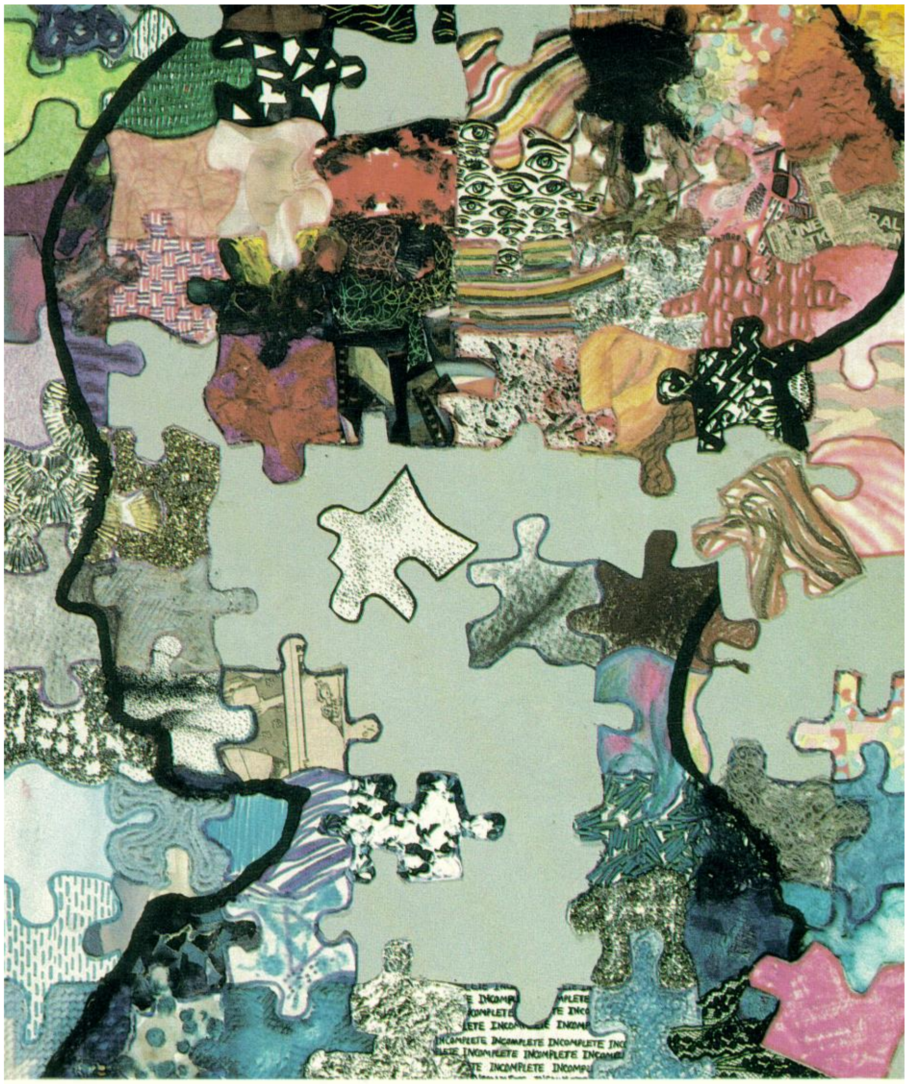
NATIONAL SCIENCE FOUNDATION 2012 ENGINEERING SENIOR DESIGN PROJECTS TO AID PERSONS WITH DISABILITIES



Edited By
John D. Enderle

NATIONAL SCIENCE FOUNDATION

2012

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FOREWORD

Welcome to the twenty-third annual issue of the National Science Foundation Engineering Senior Design Projects to Aid Persons with Disabilities. In 1988, the National Science Foundation (NSF) began a program to provide funds for student engineers at universities throughout the United States to construct custom designed devices and software for individuals with disabilities. Through the Bioengineering and Research to Aid the Disabled[1] (BRAD) program of the Emerging Engineering Technologies Division of NSF[2], funds were awarded competitively to 16 universities to pay for supplies, equipment and fabrication costs for the design projects. A book entitled NSF 1989 Engineering Senior Design Projects to Aid the Disabled was published in 1989, describing the projects that were funded during the first year of this effort.

In 1989, the BRAD program of the Emerging Engineering Technologies Division of NSF increased the number of universities funded to 22. Following completion of the 1989-1990 design projects, a second book was published describing these projects, entitled NSF 1990 Engineering Senior Design Projects to Aid the Disabled.

North Dakota State University (NDSU) Press published the following three issues. In the NSF 1991 Engineering Senior Design Projects to Aid the Disabled almost 150 projects by students at 20 universities across the United States were described. The NSF 1992 Engineering Senior Design Projects to Aid the Disabled presented almost 150 projects carried out by students at 21 universities across the United States during the 1991-92 academic year. The fifth issue described 91 projects by students at 21 universities across the United States during the 1992-93 academic year.

Creative Learning Press, Inc. has published the succeeding volumes. The NSF 1994 Engineering Senior Design Projects to Aid the Disabled, published in 1997, described 94 projects carried out by students at 19 universities during the academic 1993-94 year. The NSF 1995 Engineering Senior Design Projects to Aid the Disabled, published in 1998, described 124 projects carried out by students at 19 universities during the 1994-95 academic year.

The NSF 1996 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 1999, presented 93 projects carried out by students at 12 universities during the 1995-96 academic year. The ninth issue, NSF 1997 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2000, included 124 projects carried out by students at 19 universities during the 1996-97 academic year. NSF 1998 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2001, presented 118 projects carried out by students at 17 universities during the 1997-98 academic year. NSF 1999 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2001, presented 117 projects carried out by students at 17 universities during the 1998-99 academic year.

NSF 2000 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2002, presented 127 projects carried out by students at 16 universities during the 1999-2000 academic year. In 2002, NSF 2001 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 134 projects carried out by students at 19 universities during the 2000-2001 academic year. NSF 2002 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2004, presented 115 projects carried out by students at 16 universities during the 2001-2002 academic year. In 2005, NSF 2003 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 134 projects carried out by students at 19 universities during the 2002-2003 academic year.

[1] The program name is now called the General & Age-Related Disabilities Engineering program.

[2] This program is now in the Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET).

NSF 2004 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2005, presented 173 projects carried out by students at 17 universities during the 2003-2004 academic year. In 2006, NSF 2005 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 154 projects carried out by students at 16 universities during the 2004-2005 academic year. NSF 2006 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2007, presented 152 projects carried out by students at 15 universities during the 2005-2006 academic year. In 2010, NSF 2007 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 139 projects carried out by students at 16 universities during the 2006-2007 academic year. NSF 2008 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2011, presented 118 projects carried out by students at 12 universities during the 2007-2008 academic year. In 2011, NSF 2009 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 160 projects carried out by students at 19 universities during the 2009-2010 academic year. NSF 2010 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2012, presented 155 projects carried out by students at 16 universities during the 2009-2010 academic year. In 2013, NSF 2011 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 129 projects carried out by students at 17 universities during the 2010-2011 academic year.

This book, funded by the NSF, describes and documents the NSF-supported senior design projects during the twenty-third year of this effort, 2011-2012. After the 5th chapter, each chapter describes the projects carried out at a single university, and was written by the principal investigator(s) at that university and revised by the editor of this publication. Individuals desiring more information on a particular design should contact the designated supervising principal investigator. An index is provided so that projects may be easily identified by topic. Chapters on best practices in design experiences, outcomes assessment, and writing about and working with individuals who have disabilities are also included in this book.

Hopefully this book will enhance the overall quality of future senior design projects, directed toward persons with disabilities, by providing examples of previous projects, and also motivate faculty at other universities to participate because of the potential benefits to students, schools, and communities. Moreover, the new technologies used in these projects will provide examples in a broad range of applications for new engineers. The ultimate goal of this publication, and all the projects built under this initiative, is to assist individuals with disabilities in reaching their maximum potential for enjoyable and productive lives.

This NSF program has brought together individuals with widely varied backgrounds. Through the richness of their interests, a wide variety of projects has been completed and is in use. A number of different technologies were incorporated in the design projects to maximize the impact of each device on the individual for whom it was developed. A two-page project description format is generally used in this text. Each project is introduced with a nontechnical description, followed by a summary of impact that illustrates the effect of the project on an individual's life. A detailed technical description then follows. Photographs and drawings of the devices and other important components are incorporated throughout the manuscript.

Sincere thanks are extended to Dr. Allen Zelman, a former Program Director of the NSF BRAD program, for being the prime enthusiast behind this initiative. Additionally, thanks are extended to Drs. Peter G. Katona, Karen M. Mudry, Fred Bowman, Carol Lucas, Semahat Demir, Robert Jaeger, Gil Devey and Ted Conway, former and current NSF Program Directors of the Biomedical Engineering and Research to Aid Persons with Disabilities Programs, who have continued to support and expand the program.

I acknowledge and thank Ms. Shari Valenta for the cover illustration and the artwork throughout the book, drawn from her observations at the Children's Hospital Accessibility Resource Center in Denver, Colorado.

The information in this publication is not restricted in any way. Individuals are encouraged to use the project descriptions in the creation of future design projects for persons with disabilities. The NSF and the editor make no representations or warranties of any kind with respect to these design projects, and specifically disclaim any liability for any incidental or consequential damages arising from the use of this publication. Faculty members using the book as a guide should exercise good judgment when advising students.

Readers familiar with previous editions of this book will note that I moved from North Dakota State University to the University of Connecticut in 1995. With that move, annual publications also moved from NDSU Press to Creative Learning Press Inc. in 1997. During 1994, I also served as NSF Program Director for the Biomedical Engineering and Research Aiding Persons with Disabilities Program while on a leave of absence from NDSU. Brooke Hallowell, a faculty member at Ohio University, became the co-editor of this book series beginning with the 1996 edition and ended with the 2007 edition to devote time to other pursuits.

Previous editions of this book are available for viewing at the web site for this project:

http://nsf-pad.bme.uconn.edu/

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ENGINEERING SENIOR DESIGN PROJECTS TO AID PERSONS WITH DISABILITIES

CHAPTER 1
INTRODUCTION

Devices and software to aid persons with disabilities often require custom modification. They are sometimes prohibitively expensive or even nonexistent. Many persons with disabilities have limited access to current technology and custom modification of available devices. Even when available, personnel costs for engineering and support make the cost of custom modifications beyond the reach of many of the persons who need them.

In 1988, the National Science Foundation (NSF), through its Emerging Engineering Technologies Division, initiated a program to support student engineers at universities throughout the United States in designing and building devices for persons with disabilities. Since its inception, this NSF program (originally called Bioengineering and Research to Aid the Disabled, then Bioengineering and Research to Aid the Disabled, and now the General & Age-Related Disabilities Engineering program) has enhanced educational opportunities for students and improved the quality of life for individuals with disabilities. Students and faculty provide, through their Accreditation Board for Engineering and Technology (ABET) accredited senior design class, engineering time to design and build the device or software. The NSF provides funds, competitively awarded to universities for supplies, equipment and fabrication costs for the design projects.

Outside of the NSF program, students are typically involved in design projects that incorporate academic goals for solid curricular design experiences, but that do not necessarily enrich the quality of life for persons other than, perhaps, the students themselves. For instance, students might design and construct a stereo receiver, a robotic unit that performs a household chore, or a model racecar.

Under this NSF program, engineering design students are involved in projects that result in original devices, or custom modifications of devices, that improve the quality of life for persons with disabilities. The students have opportunities for practical and creative problem solving to address well-defined needs, and while persons with disabilities receive the products of that process at no financial cost. Upon completion, each finished project becomes the property of the individual for whom it was designed.

The emphasis of the program is to:

- Provide children and adults with disabilities student-engineered devices or software to improve their quality of life and provide greater self-sufficiency,
- Enhance the education of student engineers through the designing and building of a device or software that meets a real need, and
- Allow participating universities an opportunity for unique service to the local community.

Local schools, clinics, health centers, sheltered workshops, hospitals, and other community agencies participate in the effort by referring interested individuals to the program. A single student or a team of students specifically designs each project for an individual or a group of individuals. Examples of projects completed in past years include laser-pointing devices for people who cannot use their hands, speech aids, behavior modification devices, hands-free automatic telephone answering and hang-up systems, and infrared systems to help individuals who are blind navigate through indoor spaces. The students participating in this program are richly rewarded through their activity with persons with disabilities, and justly experience a unique sense of purpose and pride in their accomplishments.

The Current Book

This book describes the NSF supported senior design projects during the academic year 2011-2012. The purpose of this publication is threefold. First, it is to serve as a reference or handbook for future senior design projects. Students are exposed to this unique body of applied information on current technology in this and previous editions of this book. This provides an even broader education than typically experienced in an undergraduate curriculum, especially in the area of rehabilitation design. Many technological advances originate from work in the space, defense, entertainment, and communications industry. Few of these advances have been applied to the rehabilitation field, making the contributions of this NSF program all the more important.

Secondly, it is hoped that this publication will serve to motivate students, graduate engineers and others to work more actively in rehabilitation. This will ideally lead to an increased technology and knowledge base to address effectively the needs of persons with disabilities.

Thirdly, through its initial chapters, the publication provides an avenue for motivating and informing all involved in design projects concerning specific means of enhancing engineering education through design experiences.

This introduction provides background material on the book and elements of design experiences. The second chapter highlights specific aspects of some exemplary practices in design projects to aid persons with disabilities. The third chapter addresses assessment of outcomes related to design projects to aid persons with disabilities. The fourth chapter provides details on enhancing students' writing skills through the senior design experience. The fifth chapter addresses the importance of fostering relationships between students and individuals with disabilities.

After the five introductory chapters, 18 chapters follow, with each chapter devoted to one participating school. At the start of each chapter, the school and the principal investigator(s) are identified. Each project description is written using the following format. On the first page, the individuals involved with the project are identified, including the student(s), the professor(s) who supervised the project, and key professionals involved in the daily lives of the individual for whom the project has been developed. A brief nontechnical description of the project follows with a summary of how the project has improved a person's quality of life. A photograph of the device or modification is usually included. Next, a technical description of the device or modification is given, with parts specified in cases where it may be difficult to fabricate them otherwise. An approximate cost of the project, excluding personnel costs, is provided.

Most projects are described in two pages. However, the first or last project in each chapter is usually significantly longer and contains more analytic content. Individuals wishing more information on a particular design should contact the designated supervising principal investigator.

Some of the projects described are custom modifications of existing devices, modifications that would be prohibitively expensive were it not for the student engineers and this NSF program. Other projects are unique one-of-a-kind devices wholly designed and constructed by students for specific individuals.

Engineering Design

As part of the accreditation process for university engineering programs, students are required to complete a minimum number of design credits in their course of study, typically at the senior level.[3,4,5]

[3] Accrediting Board for Engineering and Technology. Accreditation Policy and Procedure Manual Effective for Evaluations for the 2010-2011 Accreditation Cycle. ABET: Baltimore, MD.

[4] Accrediting Board for Engineering and Technology. Criteria for Accrediting Engineering Programs, 2010-2011. ABET: Baltimore, MD.

[5] Enderle, J.D., Gassert, J., Blanchard, S.M., King, P., Beasley, D., Hale Jr., P. and Aldridge, D., The ABCs

Many call this the capstone course. Engineering design is a course or series of courses that brings together concepts and principles that students learn in their field of study. It involves the integration and extension of material learned throughout an academic program to achieve a specific design goal. Most often, the student is exposed to system-wide analysis, critique and evaluation. Design is an iterative decision-making process in which the student optimally applies previously learned material to meet a stated objective.

There are two basic approaches to teaching engineering design, the traditional or discipline-dependent approach, and the holistic approach. The traditional approach involves reducing a system or problem into separate discipline-defined components. This approach minimizes the essential nature of the system as a holistic or complete unit, and often leads participants to neglect the interactions that take place between the components. The traditional approach usually involves a sequential, iterative approach to the system or problem, and emphasizes simple cause-effect relationships.

A more holistic approach to engineering design is becoming increasingly feasible with the availability of powerful computers and engineering software packages, and the integration of systems theory, which addresses interrelationships among system components as well as human factors. Rather than partitioning a project based on discipline-defined components, designers partition the project according to the emergent properties of the problem.

A design course provides opportunities for problem solving relevant to large-scale, open-ended, complex, and sometimes ill-defined systems. The emphasis of design is not on learning new material. Typically, there are no required textbooks for the design course, and only a minimal number of lectures are presented to the student. Design is best described as an individual study course where the student:

- Selects the device or system to design,
- Writes specifications,
- Creates a paper design,
- Analyzes the paper design,
- Constructs the device,
- Evaluates the device,
- Documents the design project, and
- Presents the project to a client.

Project Selection

In a typical NSF design project, the student meets with the client (a person with a disability and/or a client coordinator) to assess needs and identify a useful project. Often, the student meets with many clients before finding a project for which his or her background is suitable.

After selecting a project, the student then writes a brief description of the project for approval by the faculty supervisor. Since feedback at this stage of the process is vitally important for a successful project, students usually meet with the client once again to review the project description.

Teams of students often undertake projects. One or more members of a team meet with one or more clients before selecting a project. After project selection, the project is partitioned by the team into logical parts where each student is assigned one of these parts. Usually, a team leader is elected by the team to ensure that project goals and schedules are satisfied. A team of students generally carries out multiple projects.

Project selection is highly variable depending on the university and the local health care facilities. Some universities make use of existing technology to develop projects by accessing databases such as ABLEDATA. ABLEDATA includes information on types of assistive technology, consumer guides, manufacturer directories, commercially available devices, and one-of-a-kind customized devices. In total, this database has over 23,000 products from 2,600 manufacturers and is available from:

http://www.abledata.com

or

(800) 227-0216.

More information about this NSF program is available at:

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of Preparing for ABET, IEEE *EMB Magazine*, Vol. 22, No. 4, 122-132, 2003 http://nsf-pad.bme.uconn.edu

Specifications

One of the most important parts of the design process is determining the specifications, or requirements that the design project must fulfill. There are many different types of hardware and software specifications.

Prior to the design of a project, a statement as to how the device will function is required. Operational specifications are incorporated in determining the problem to be solved. Specifications are defined such that any competent engineer is able to design a device that will perform a given function. Specifications determine the device to be built, but do not provide information about how the device is built. If several engineers design a device from the same specifications, all of the designs would perform within the given tolerances and satisfy the requirements; however, each design would be different. Manufacturers' names are generally not stated in specifications, especially for electronic or microprocessor components, so that design choices for future projects are not constrained.

If the design project involves modifying an existing device, the modification is fully described in detail. Specific components of the device, such as microprocessors, LEDs, and electronic parts, are described. Descriptive detail is appropriate because it defines the environment to which the design project must interface. However, the specifications for the modification should not provide detailed information about how the device is to be built.

Specifications are usually written in a report that qualitatively describes the project as completely as possible, and how the project will improve the life of an individual. It is also important to explain the motivation for carrying out the project. The following issues are addressed in the specifications:

- What will the finished device do?
- What is unusual about the device?

Specifications include a technical description of the device, and all of the facts and figures needed to complete the design project. The following are examples of important items included in technical specifications:

- Electrical parameters (including interfaces, voltages, impedances, gains, power output, power input, ranges, current capabilities, harmonic distortion, stability, accuracy, precision, and power consumption)
- Mechanical parameters (including size, weight, durability, accuracy, precision, and vibration)
- Environmental parameters (including location, temperature range, moisture, and dust)

Paper Design and Analysis

The next phase of the design is the generation of possible solutions to the problem based on the specifications, and selection of an optimal solution. This involves creating a paper design for each of the solutions and evaluating performance based on the specifications. Since design projects are open-ended, many solutions exist. Solutions often require a multidisciplinary system or holistic approach to create a successful and useful product. This stage of the design process is typically the most challenging because of the creative aspect to generating solutions.

The specifications previously described are the criteria for selecting the best design solution. In many projects, some specifications are more important than others, and trade-offs between specifications may be necessary. In fact, it may be impossible to design a project that satisfies all of the design specifications. Specifications that involve some degree of flexibility are helpful in reducing the overall complexity, cost and effort in carrying out the project. Some specifications are absolute and cannot be relaxed.

Most projects are designed in a top-down approach similar to the approach of writing computer software by first starting with a flow chart. After the flow chart or block diagram is complete, the next step involves providing additional details to each block in the flow chart. This continues until sufficient detail exists to determine whether the design meets the specifications after evaluation.

To select the optimal design, it is necessary to analyze and evaluate the possible solutions. For ease in analysis, it is usually easiest to use computer software. For example, National Instrument's *Multisim*, a circuit analysis program, easily analyzes circuit problems and creates the layout for a printed circuit board. For mechanical components, the use of Dassault Systèmes SolidWorks Corp. *Solidworks* allows for computer-aided-design analysis and 3D drawings. Other situations require that a potential design project solution be partially constructed or breadboarded for analysis and evaluation. After analysis of all possible solutions, the optimal design selected is the one that meets the specifications most closely.

Construction and Evaluation of the Device

After selecting the optimal design, the student then constructs the device. The best method of construction is often to build the device module by module. By building the project in this fashion, the student is able to test each module for correct operation before adding it to the complete device. It is far easier to eliminate problems module by module than to build the entire project and then attempt to eliminate problems.

Design projects are analyzed and constructed with safety as one of the highest priorities. Clearly, the design project that fails should fail in a safe manner, without any dramatic and harmful outcomes to the client or those nearby. An example of a fail-safe mode of operation for an electrical device involves grounding the chassis, and using appropriate fuses; if ever a 120-V line voltage short circuit to the chassis should develop, a fuse would blow and no harm to the client would occur. Devices should also be protected against runaway conditions during the operation of the device and during periods of rest. Failure of any critical components in a device should result in the complete shutdown of the device.

After the project has undergone laboratory testing, it is then tested in the field with the client. After the field test, modifications are made to the project, and the project is given to the client. Ideally, the project in use by the client should be evaluated periodically for performance and usefulness after the project is complete. Evaluation typically occurs, however, when the device no longer performs adequately for the client, and it is returned to the university for repair or modification. If the repair or modification is simple, a university technician may handle the problem. If the repair or modification is more extensive, another design student may be assigned to the project to handle the problem as part of his or her design course requirements.

Documentation

Throughout the design process, the student is required to document the optimal or best solution to the problem through a series of written assignments. For the final report, documenting the design project involves integrating each of the required reports into a single final document. While this should be a simple exercise, it is often a most vexing and difficult endeavor. Many times during the final stages of the project, some specifications are changed, or extensive modifications to the ideal paper design are necessary.

Most universities require that the final report be professionally prepared using desktop publishing software. This requires that all circuit diagrams and mechanical drawings be professionally drawn. Illustrations are usually drawn with computer software.

The two-page reports within this publication are not representative of the final reports submitted for design course credit; they are summaries of the final reports. A typical final report for a design project is approximately 30 pages in length, and includes extensive analysis supporting the operation of the design project. Photographs of the device may be included in the final report but mechanical and electrical diagrams are often more useful in documenting the device.

CHAPTER 2
BEST PRACTICES IN SENIOR DESIGN

John Enderle and Brooke Hallowell

This chapter presents different approaches to the design course experience. For example, at Texas A&M University, the students worked on many small design projects during the two-semester senior design course sequence. At North Dakota State University, students worked on a single project during the two-semester senior design course sequence. At the University of Connecticut, students were involved in a web-based approach and in distance learning in a collaborative arrangement with Ohio University.

Duke University

The Devices for the Persons with Disabilities course is offered as an elective to seniors and graduate students through the Biomedical Engineering Department at Duke University. The course has been supported since September 1996 by grants from the National Science Foundation, and is offered each fall. The course is limited to 12 students and four to six projects to provide a team atmosphere and to ensure quality results.

The course involves design, construction and delivery of a custom assistive technology device; typically in one semester. At the start of the semester, students are given a list of descriptions for several possible projects that have been suggested by persons with disabilities and health care workers in the local community. Students individually rank order the list, and for their top three selections, describe why they are interested and what skills they possess that will help them be successful. Projects are assigned to teams of one to three students based on these interests and expected project difficulty. Soon thereafter, students meet with the project's supervisor and client. The supervisor is a health care professional, typically a speech-language pathologist or occupational or physical therapist, who has worked with the client. Student teams then formulate a plan for the project and present an oral and written project proposal to define the problem and their expected approach. In the written proposal, results of a patent and product search for ideas related to the student project are summarized and contrasted with the project.

Each student keeps an individual laboratory notebook for his or her project. Copies of recent entries are turned in to the course instructor for a weekly assessment of progress. During the semester, students meet regularly with the supervisor and/or client to ensure that the project will be safe and meet the needs of the client. Three oral and written project reports are presented to demonstrate progress, to provide experience with engineering communications, and to allow a public forum for students to receive feedback from other students, supervisors, engineers, and health care professionals.

Course lectures are focused on basic principles of engineering design, oral and written communication, and ethics. In addition, guest lectures cover topics such as an overview of assistive technology, universal design, ergonomics and patent issues. Field trips to a local assistive technology lending library, and to an annual exposition featuring commercial assistive technology companies provide further exposure to the field.

Students present their projects in near-final form at a public mock delivery two weeks before their final delivery, which provides a last chance to respond to external feedback. Final oral presentations include project demonstrations. Each project's final written report includes a quantitative analysis of the design, as well as complete mechanical drawings and schematics. At the end of the semester, students deliver their completed project to the client, along with a user's manual that describes the operation, features, and specifications for the device.

For projects requiring work beyond one semester, students may continue working through the spring semester on an independent study basis. A full-time summer student provides service on projects already delivered.

University of Massachusetts-Lowell

The capstone design experience at University of Mass-Lowell is divided into two three-credit courses. These courses are taken in the last two semesters of undergraduate studies and for the most part involve the design of assistive technology devices and systems. The program costs are supported in part by a five-year grant from the National Science Foundation. Additional funding comes from corporate and individual donations to the assistive technology program at University of Mass-Lowell. Both courses are presented in each semester of a traditional academic year. The combined enrollment averages between 40 and 50 each semester.

The major objective of the first course is for each student to define a major design to be accomplished prior to graduation and ideally within the timeframe of the second course. The process for choosing a design project begins immediately. However, there are other activities that take place concurrently with the search for a project. The most significant of these is a team effort to generate a business plan for securing venture capital or other forms of financing to support corporate development of a product oriented towards the disadvantaged community. The instructor chooses a number of students to serve as CEOs of their company. The remaining students must present oral and written resumes and participate in interviews.

The CEO of each company must then hire his or her employees and the teams are thus formed. Each team is expected to do the following:

- Determine a product,
- Name the company,
- Determine the process for company name registration,
- Generate a market analysis,
- Determine the patent process,
- Generate a cost analysis for an employee benefit package,
- Generate information on such terms as FICA, FUTA, SS, 941, MC, IRA, SRA, I9, and other terms relative to payroll deductions and state and federal reporting requirements,
- Meet with patent attorneys, real estate agents, members of the business community, bankers, and a venture capitalist,
- Demonstrate understanding of the cost of insurance and meet with insurance agents to discuss health and life insurance for employees and liability insurance costs for the company, and
- Explore OSHA requirements relative to setting up development laboratories.

Students carry out these tasks using direct person-to-person contact and the vast amount of information on the Internet.

The teams are also required to understand the elements of scheduling and must produce a Gant chart indicating the tasks and allotted times to take their product through development and make ready for manufacture. A cost analysis of the process is required, and students are expected to understand the real cost of development, with overhead items clearly indicated.

Much of the subject material described above is covered in daily classroom discussions and with guest speakers. During the process of generating the team business plan, each team is required to present two oral reports to the class. The first is a company report describing their company, assigned tasks, their product, and a rationale for choosing their product.

The second is a final report that is essentially a presentation of the company business plan. Technical oral and written reports are essential components of the first course. Two lectures are presented on the techniques of oral presentations and written reports are reviewed by the college technical writing consultants. All oral presentation must be made using PowerPoint or other advanced creative tools.

Early in the course, potential capstone projects are presented; students are required to review current and past projects. In some semesters, potential clients address the class. Representatives from agencies have presented their desires and individuals in wheelchairs have presented their requests to the class. Students are required to begin the process of choosing a project by meeting with potential clients and assessing the problem, defining the needs, and making a decision as to whether or not they are interested in the associated project. In some cases, students interview and discuss as many as three or four potential projects before finding one they feel confident in accomplishing. If the project is too complex for a single student, a team is formed. The decision to form a team is made by the instructor only after in-depth discussions with potential team members. Individual responsibilities must be identified as part of a team approach to design. Once a project has been chosen, the student must begin the process of generating a written technical proposal. This document must clearly indicate answers to the following questions:

- What are the project and its technical specifications?
- Why is the project necessary?
- What technical approach is to be used to accomplish the project?
- How much time is necessary?
- How much will the project cost?

The final activity in this first course is the oral presentation of the proposal.

The second course is concerned with the design of the project chosen and presented in the first course. In the process of accomplishing the design, students must present a total of five written progress reports, have outside contacts with a minimum of five different persons, and generate at least three publications or public presentations concerning their project. Finally, they demonstrate their project to the faculty, write a final comprehensive technical report, and deliver the project to their client.

Texas A&M University

The objective of the NSF program at Texas A&M University is to provide senior bioengineering students an experience in the design and development of rehabilitation devices and equipment to meet explicit client needs identified at several off-campus rehabilitation and education facilities. The students meet with therapists and/or special education teachers for problem definition under faculty supervision. This program provides significant real-world design experiences, emphasizing completion of a finished product. Moreover, the program brings needed technical expertise that would otherwise not be available to not-for-profit rehabilitation service providers. Additional benefits to the participating students include a heightened appreciation of the problems of persons with disabilities, motivation toward rehabilitation engineering as a career path, and recognition of the need for more long-term research to address the problems for which today's designs are only an incomplete solution.

Texas A&M University's program involves a two-course capstone design sequence, BIEN 441 and 442. BIEN 441 is offered during the fall and summer semesters, and BIEN 442 is offered during the spring semester. The inclusion of the summer term allows a full year of ongoing design activities. Students are allowed to select a rehabilitation design project, or another general bioengineering design project.

The faculty members at Texas A&M University involved with the rehabilitation design course have worked in collaboration with the local school districts, community rehabilitation centers, residential units of the Texas Department of Mental Health and Mental Retardation (MHMR), community outreach programs of Texas MHMR, and individual clients of the Texas Rehabilitation Commission and the Texas Commission for the Blind. Appropriate design projects are identified in group meetings between the staff of the collaborating agency, the faculty, and the participating undergraduate students enrolled in the design class. In addition, one student is employed in the design laboratory during the summer to provide logistical support, and pursue his or her own project. Each student is required to participate in the project definition session, which enriches the overall design experience. The meetings take place at the beginning of each semester, and periodically thereafter as projects are completed and new ones are identified.

The needs expressed by the collaborating agencies often result in projects that vary in complexity and duration. To meet the broad spectrum of needs, simpler projects are accommodated by requiring rapid completion, at which point the students move on to another project. More difficult projects involve one or more semesters, or even a year's effort; these projects are the ones that typically require more substantial quantitative and related engineering analysis.

Following the project definition, the students proceed through the formal design process of brainstorming, clarification of specifications, preliminary design, review with the collaborating agency, design execution and safety analysis, documentation, prerelease design review, and delivery and implementation in the field. The execution phase of the design includes identifying and purchasing necessary components and materials, arranging for any fabrication services that may be necessary, and obtaining photography for project reports.

Throughout each phase of the project, a faculty member supervises the work, as do the university supported teaching assistants assigned to the rehabilitation engineering laboratory. The students also have continued access to the agency staff for clarification or revision of project definitions, and review of preliminary designs. The latter is an important aspect of meeting real needs with useful devices. The design team meets as a group to discuss design ideas and project progress, and to plan further visits to the agencies.

One challenging aspect of having students responsible for projects that are eagerly anticipated by the intended recipient is the variable quality of student work, and the inappropriateness of sending inadequate projects into the field. This potential problem is resolved at Texas A&M University by continuous project review, and by requiring that the projects be revised and reworked until they meet faculty approval.

At the end of each academic year, the faculty member and the personnel from each collaborating agency assess which types of projects met with the greatest success in achieving useful delivered devices. This review has provided ongoing guidance in the selection of future projects. The faculty members also maintain continuous contact with agency personnel with respect to ongoing and past projects that require repair or modification. In some instances, repairs are assigned as short-term projects to currently participating students. This provides excellent lessons in the importance of adequate documentation.

Feedback from participating students is gathered each semester using the Texas A&M University student questionnaire form as well as personal discussion. The objective of the reviews is to obtain students' assessment of the educational value of the rehabilitation design program, the adequacy of the resources and supervision, and any suggestions for improving the process.

North Dakota State University

All senior electrical engineering students at North Dakota State University (NDSU) are required to complete a two-semester senior design project as part of their study. These students are partitioned into faculty-supervised teams of four to six students. Each team designs and builds a device for a particular individual with a disability in eastern North Dakota or western Minnesota.

During the early stages of NDSU's participation in projects to aid persons with disabilities, a major effort was undertaken to develop a complete and workable interface between the NDSU electrical engineering department and the community of persons with disabilities to identify potential projects. These organizations are the Fargo Public School System, NDSU Student Services and the Anne Carlson School. NDSU students visit potential clients or their supervisors to identify possible design projects at one of the cooperating organizations. All of the senior design students visit one of these organizations at least once. After the site visit, the students write a report on at least one potential design project, and each team selects a project to aid a particular individual.

The process of a design project is implemented in two parts. During the first semester of the senior year, each team writes a report describing the project to aid an individual. Each report includes an introduction, establishing the need for the project. The body of the report describes the device; a complete and detailed engineering analysis is included to establish that the device has the potential to work. Almost all of the NDSU projects involve an electronic circuit. Typically, devices that involve an electrical circuit are analyzed using PSpice, or another software analysis program. Extensive testing is undertaken on subsystem components using breadboard circuit layouts to ensure a reasonable degree of success before writing the report. Circuits are drawn for the report using OrCAD, a CAD program. The OrCAD drawings are also used in the second phase of design, which allows the students to bring a circuit from the schematic to a printed circuit board with relative ease.

During the second semester of the senior year, each team builds the device to aid an individual. This first involves breadboarding the entire circuit to establish the viability of the design. After verification, the students build printed circuit boards using OrCAD, and then finish the construction of the projects using the fabrication facility in the electrical engineering department. The device is then fully tested, and after approval by the senior design faculty advisor, the device is given to the client. Each of the student design teams receives feedback throughout the year from the client or client coordinator to ensure that the design meets its intended goal.

Each design team provides an oral presentation during regularly held seminars in the department. In the past, local TV stations have filmed the demonstration of the senior design projects and broadcast the tape on their news shows. This media exposure usually results in viewers contacting the electrical engineering department with requests for projects to improve the life of another individual, further expanding the impact of the program.

Design facilities are provided in three separate laboratories for analysis, prototyping, testing, printed circuit board layout, fabrication, and redesign or development. The first laboratory is a room for team meetings during the initial stages of the design. Data books and other resources are available in this room. There are also 12 workstations available for teams to test their designs, and verify that the design parameters have been met. These workstations consist of a power supply, a waveform generator, an oscilloscope, a breadboard, and a collection of hand tools.

The second laboratory contains computers for analysis, desktop publishing and microprocessor testing. The computers all have analysis, CAD and desktop publishing capabilities so that students may easily bring their design projects from the idea to the implementation stage. A scanner with image enhancement software and a high-resolution printer are also available in the laboratory.

The third laboratory is used by the teams for fabrication. Six workstations exist for breadboard testing, soldering, and finish work involving printed circuit boards. Sufficient countertop space exists so that teams may leave their projects in a secure location for ease of work.

The electrical engineering department maintains a relatively complete inventory of electronic components necessary for design projects, and when not in stock, has the ability to order parts with minimal delay. The department also has a teaching assistant assigned to this course on a year-round basis, and an electronics technician available for help in the analysis and construction of the design project.

There are occasionally projects constructed at NDSU (and at other universities) that prove to be unsafe or otherwise unusable for the intended individual, despite the best efforts of the student teams under the supervision of the faculty advisors. These projects are not officially documented.

University of Connecticut

In August 1998 the Department of Electrical & Systems Engineering (ESE) at the University of Connecticut (UConn), in collaboration with the School of Hearing, Speech and Language Sciences at Ohio University, received a five-year NSF grant for senior design experiences to aid persons with disabilities. An additional five-year grant was awarded in 2005. These NSF projects are a pronounced change from previous design experiences at UConn, which involved industry sponsored projects carried out by a team of student engineers. The new Biomedical Engineering Program at UConn has now replaced the ESE Department in this effort.

To provide effective communication between the sponsor and the student teams, a web-based approach was implemented.[6] Under the new scenario, students work individually on a project and are divided into teams for weekly meetings. The purpose of the team is to provide student-derived technical support at weekly meetings. Teams also form throughout the semester based on needs to solve technical problems. After the problem is solved, the team dissolves and new teams are formed.

Each year, 25 projects are carried out by the students at UConn. Five of the 25 projects are completed through collaboration with personnel at Ohio University using varied means of communication currently seen in industry, including video conferencing, the Internet, telephone, e-mail, postal mailings, and video recordings.

Senior design consists of two required courses, Design I and II. Design I is a three-credit hour course in which students are introduced to a variety of subjects. These include: working in teams, design

[6] Enderle, J.D., Browne, A.F., and Hallowell, B. (1998). A WEB Based Approach in Biomedical Engineering Design Education. Biomedical Sciences Instrumentation, 34, pp. 281-286.

process, planning and scheduling (timelines), technical report writing, proposal writing, oral presentations, ethics in design, safety, liability, impact of economic constraints, environmental considerations, manufacturing, and marketing. Each student in Design I:

- Selects a project to aid an individual after interviewing a people with disabilities,
- Drafts specifications,
- Prepares a project proposal,
- Selects an optimal solution and carries out a feasibility study,
- Specifies components, conducts a cost analysis and creates a time-line, and
- Creates a paper design with extensive modeling and computer analysis.

Design II is a three-credit-hour course following Design I. This course requires students to implement a design by completing a working model of the final product. Prototype testing of the paper design typically requires modification to meet specifications. These modifications undergo proof of design using commercial software programs commonly used in industry. Each student in Design II:

- Constructs and tests a prototype using modular components as appropriate,
- Conducts system integration and testing,
- Assembles a final product and field-tests the device,
- Writes a final project report,
- Presents an oral report using PowerPoint on Senior Design Day, and
- Gives the device to the client after a waiver is signed.

Course descriptions, student project homepages and additional resources are located at http://www.bme.uconn.edu/bme/ugrad/bmesdi-ii.htm.

The first phase of the on-campus projects involves creating a database of persons with disabilities and then linking each student with a person who has a disability. The A.J. Pappanikou Center provides an MS Access database with almost 60 contacts and a short description of disabilities associated with the clients in each. The involvement of the Center was essential for the success of the program. The A.J. Pappanikou Center is Connecticut's University Affiliated Program (UAP) for disabilities studies. As such, relationships have been established with the Connecticut community of persons affected by disabilities, including families, caregivers, advocacy and support groups and, of course, persons with disabilities themselves. The Center serves as the link between the person in need of the device and the design course staff. The Center has established ongoing relationships with Connecticut's Regional Educational Service Centers, the Birth to Three Network, the Connecticut Tech Act Project, and the Department of Mental Retardation. Through these contacts, the Center facilitates the interaction between the ESE students, the client coordinators (professionals providing support services, such as speech-language pathologists and physical and occupational therapists), individuals with disabilities (clients), and clients' families.

The next phase of the course involves students' selection of projects. Using the on-campus database, each student selects two clients to interview. The student and a UConn staff member meet with the client and client coordinator to identify a project that would improve the quality of life for the client. After the interview, the student writes a brief description for each project. Almost all of the clients interviewed have multiple projects. Project descriptions include contact information (client, client coordinator, and student name) and a short paragraph describing the problem. These reports are collected, sorted by topic area, and put into a Project Notebook. In the future, these projects will be stored in a database accessible from the course server for ease in communication.

Each student then selects a project from a client that he or she has visited, or from the Project Notebook. If the project selected was from the Project Notebook, the student visits the client to further refine the project. Because some projects do not require a full academic year to complete, some students work on multiple projects. Students submit a project statement that describes the problem, including a statement of need, basic preliminary requirements, basic limitations, other data accumulated, and important unresolved questions.

Specific projects at Ohio University are established via distance communication with the co-principal investigator, who consults with a wide array of service providers and potential clients in the Athens, Ohio region.

The stages of specification, project proposal, paper design and analysis, construction and evaluation, and documentation are carried out as described earlier in the overview of engineering design.

To facilitate working with sponsors, a web-based approach is used for reporting the progress on projects. Students are responsible for creating their own Internet sites that support both html and pdf formats with the following elements:

- Introduction for the layperson,
- Resume,
- Weekly reports,
- Project statement,
- Specifications,
- Proposal, and
- Final Report.

Teamwork

Student learning styles differ among team members. Gender, cultural factors, personality type, intelligence, previous educational background, academic achievement, and previous experience in teams may influence the strengths and weaknesses that individuals bring to team membership. Research pertaining to differences in cognitive style characterized by field dependence versus independence helps to shed light on individual differences among team members and how those differences may affect team interactions[7,8]. There is strong empirical evidence in numerous disciplines suggesting that students may benefit from explicit training to compensate for or enhance the cognitive style with which they enter an educational experience, such as a senior design course.[9,10,11]

Research on effective teamwork suggests that key variables that should be attended to for optimal team performance include:

- Explicit sharing of the group's purpose among all team members,
- Concerted orientation to a common task,
- Positive rapport among team members,
- Responsiveness to change,
- Effective conflict management,
- Effective time management, and
- Reception and use of ongoing constructive feedback.

According to the literature on cooperative learning in academic contexts,[12,13] the two most essential determiners for success in teamwork are positive interdependence and individual accountability. Positive interdependence, or effective synergy among team members, leads to a final project or design that is better than any of the individual team members may have created alone. Individual accountability, or an equal sharing of workload, ensures that no team member is overburdened and also that every team member has an equal learning opportunity and hands-on experience.

Because students are motivated to work and learn according the way they expect to be assessed, grading of specific teamwork skills of teams and of individual students inspires teams' and individuals' investment in targeted learning outcomes associated with

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7 Tinajero, C., & Paramo, M. F. (1997). Field dependence-independence and academic achievement: A re-examination of their relationship. *British Journal of Educational Psychology, 67*, *2*, 199-212.

8 Witkin, H.A., & Goodenough, D.R. (1981). *Cognitive Styles: Essence and Origins.* International Universities Press, Inc., NY.

9 Deming, W. (1986). *Out of the crisis: quality, productivity, and competitive position*. Cambridge, Massachusetts: Cambridge University Press.

10 Katzenbach, J. & Smith, D. (1993). *The wisdom of teams: creating the high-performance organization.* Boston, Massachusetts: Harvard Business School Press.

11 Larson, C. & LaFasto, F. (1989). *Teamwork: what must go right, what can go wrong.* Newbury Park, California: SAGE Publications.

12 Cottell, P.G. & Millis, B.J. (1994). Complex cooperative learning structures for college and university courses. In To improve the Academy: Resources for students, faculty, and institutional development. Stillwater, OK: New Forums Press.

13 Jaques, D. (1991). Learning in groups, 2nd edition. Guilford, Surrey, England: Society for Research into Higher Education.

teamwork. Teamwork assessment instruments have been developed in numerous academic disciplines and can be readily adapted for use in engineering design projects.

Clearly targeting and assessing teamwork qualities may help to alleviate conflicts among team members. In general, most team members are dedicated to the goals of the project and excel beyond all expectations. When there is a breakdown in team synergy, instructors may sometimes be effective in facilitating conflict resolution.

Timeline development by the team is vital to success, eliminates most management issues, and allows the instructor to monitor the activities by student team members. Activities for each week must be documented for each team member, with an optimal target of five to ten activities per team member each week. When each team member knows what specific steps must be accomplished there is a greater chance of success in completing the project.

History of Teams in Senior Design at UConn

Projects Before the NSF Program

Before the NSF-sponsored program, senior design was sponsored by local industry. During these years, all of the students were partitioned into four- member teams whereby student names were selected at random to choose a particular sponsored project. The projects were complex, and team members were challenged to achieve success. All of the students met each week at a team meeting with the instructor. During the first semester, lectures on teaming and communication skills were given, as well as team skills training. No timelines were used and general project goals were discussed throughout the two semesters. A teaching assistant was used in the course as an assistant coach to help the students in whatever manner was necessary. In general, multidisciplinary teams were not formed since the student backgrounds were not the criteria used to select team members.

Procrastination, a lack of enthusiasm and poor planning were common themes among the students. Most teams encountered significant difficulties in completing projects on time. Conflict among team members was more frequent than desired, and in some extreme encounters, physical violence was threatened during lab sessions. Many students complained that the projects were too difficult, scheduling of team meetings was too challenging, their backgrounds were insufficient, they had difficulty communicating ideas and plans among team members, and they did not have enough time with outside activities and courses. A peer evaluation was used without success.

NSF Projects Year 1

During year one of the NSF senior design program, students worked individually on a project and were divided into teams for weekly meetings. The level of project difficulty was higher than previous years. The purpose of the team was to provide student-derived technical support at weekly team meetings. Students were also exposed to communication skills training during the weekly team meetings, and received feedback on their presentations. In addition, timelines were used for the first time, which resulted in greater harmony and success. The course improved relative to previous years. Many students continued working on their projects after the semester ended.

Throughout the year, students also divided themselves into dynamic teams apart from their regular teams based on needs. For example, students implementing a motor control project gathered together to discuss various alternatives and help each other. These same students would then join other dynamic teams in which a different technology need was evident. Dynamic teams were formed and ended during the semester. Both the regular team and dynamic teams were very important in the success of the projects.

Overall, students were enthusiastic about the working environment and the approach. Although students seemed content with being concerned only with their individual accomplishments, and completing a project according to specifications and on time, this approach lacked the important and enriching multidisciplinary team experience that is desired in industry.

NSF Projects Year 2
During the second year of the NSF senior design program, seven students worked on two- and three-person team projects, and the remaining students in the class worked in teams oriented around a client; that is, a single client had three students working on individual projects. These projects required integration in the same way a music system requires integration of speakers, a receiver, an amplifier, a CD player, etc. In general, when teams were formed, the instructor would facilitate the teams' multidisciplinary nature. Two teams involved mechanical engineering students and electrical engineering students. The others were confined by the homogeneity of the remaining students. All of the students met each week at a team meeting with the same expectations as previously described, including oral and written reports. Dynamic teaming occurred often throughout the semester.

While the team interaction was significantly improved relative to previous semesters, the process was not ideal. Senior Design is an extremely challenging set of courses. Including additional skill development with the expectation of success in a demanding project does not always appear to be reasonable. A far better approach would be to introduce team skills much earlier in the curriculum, even as early as the freshman year. Introducing teamwork concepts and skills earlier and throughout the curriculum would ensure an improved focus on the project itself during the senior design experience.

Timelines
At the beginning of the second semester, the students are required to update their timelines to conform to typical project management routines wherein the student focuses on concurrent activities and maps areas where project downtimes can be minimized. This updated timeline is posted on a student project web page and a hard copy is also attached to the student's workbench. This allows the professor or instructor to gauge progress and to determine whether the student is falling behind at a rate that will delay completion of the project.

Also during the second semester, the student is required to report project progress via the web on a weekly basis. Included in this report are sections of their timeline that focus on the week just past and on the week ahead. The instructor may meet with students to discuss progress or the lack thereof.

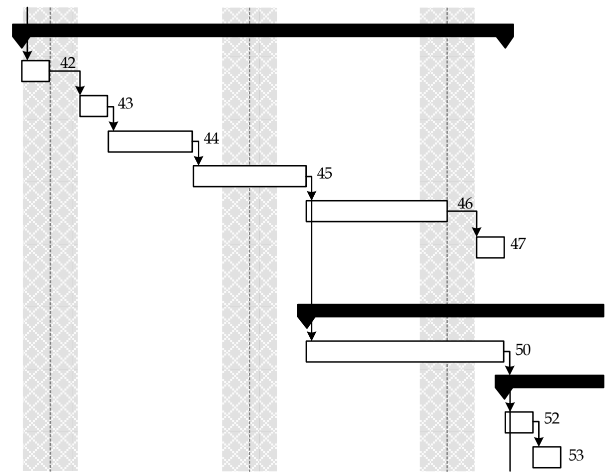

Fig. 2.1. Shown above is a section of a typical timeline. The rectangular boxes represent certain tasks to be completed. These singular tasks are grouped into larger tasks, represented by thick black lines. The tasks are numbered to correspond to a task list that is not shown. The thin lines that descend from task to task are the links. Notice that task 42 must be completed before task 43 can be started. Also, task 45 must be completed before task 46 and 50 can be started. However, task 46 and 50 are concurrent, along with task 47, and can therefore be completed at the same time. No link from task 47 shows that it is out of the critical path.

Theory
The Senior Design Lab utilizes what is perhaps the most easily understood project-planning tool: the timeline. The timeline, or Gantt chart (see Fig. 2.1), displays each task as a horizontal line that shows the starting and ending date for each task within a project and how it relates to others.

The relation of one task to another is the central part of a timeline. The student lists tasks and assigns durations to them. The student then "links" these tasks together. Linking is done in the order of what needs to happen first before something else can happen. These links are known as dependencies. An example of this is a construction project. The foundation must be poured before you can start to erect the walls. Once all dependencies are determined, the end date of the project can be determined. This line of linked dependencies is also known as the critical path.

The critical path, the series of tasks in a project that must be completed on time for the overall project to stay on time, can be examined and revised to advance the project completion date. If, after linking tasks, the timeline does not result in the required or desired completion date, it is recast. For example, sequential activities may be arranged to run in parallel, that is, concurrently to the critical path whenever this is practicable. An example of this is performing certain types of design work on sub-assembly B while injection mold parts are being manufactured for item A, which is in the critical path. In the case of the Senior Design Lab, the student would schedule report writing or familiarization of certain software packages or equipment concurrently with parts delivery or parts construction. Parallel planning prevents downtime – time is utilized to its fullest since work is always underway. The project completion date is also advanced when assigned durations of critical path tasks are altered. Concurrent tasks should be clearly delineated in the timeline for each project.

It is the planning and mapping of concurrent tasks that make the timeline a project-planning tool. In the modern working world time is a most valuable resource. The timeline facilitates time loading (resource management) by helping the project manager schedule people and resources most efficiently. For example, optimum time loading keeps a machining center from being overloaded one day and having zero work the next day. The timeline schedules "full time busy" for people and equipment, allowing for maximum pay-off and efficiency. In the machining center example, less than optimum time loading would delay any tasks that require usage of the center because a greater number of tasks are assigned than can be accomplished in the amount of time scheduled. Tasks would slide, resulting in delayed projects. The same idea of time loading is also applied to personnel resources. Less than optimal time loading could result in absurd schedules that require employees to work excessive hours to maintain project schedules.

A timeline also allows for updates in the project plan if a task requires more time than expected or if a design method turns out to be unsatisfactory, requiring that new tasks be added. These extra times or new tasks that outline the new design track are logged into the timeline with the project completion date being altered. From this information, the project manager can either alter durations of simpler tasks or make certain tasks parallel to place the new completion date within requirements.

The timeline also acts as a communication tool. Team members or advisors can see how delays will affect the completion date or other tasks in the project. Project progress is also tracked with a timeline. The project manager can see if the tasks are completed on time or measure the delay if one is present. Alterations to amount of resources or time spent on tasks are implemented to bring the project plan back on schedule. Alterations are also made by removing certain tasks from the critical path and placing them into a parallel path, if practical.

One major advantage of successful project planning using the timeline is the elimination of uncertainty. A detailed timeline has all project tasks thought out and listed. This minimizes the risk of missing an important task. A thoughtfully linked timeline also allows the manager to see what tasks must be completed before its dependent task can start. If schedule lag is noticed, more resources can be placed on the higher tasks.

Method

Discussed below is a method in which a timeline can be drawn. The Senior Design Lab utilizes Microsoft Project for project planning. Aspects such as assigning work times, workday durations, etc. are determined at this time but are beyond the scope of this chapter.

Tasks are first listed in major groups. Major groupings are anything that is convenient to the project. Major groups consist of the design and/or manufacture of major components, design type (EE, ME or programming), departmental tasks, or any number of related tasks. After the major groups are listed, they are broken down into sub-tasks. If the major group is a certain type of component, say an electro-mechanical device, then related electrical or mechanical engineering tasks required to design or build the item in the major group are listed as sub-groups. In the sub-groups the singular tasks themselves are delineated. All of the aforementioned groups, sub-groups, and tasks are listed on the left side of the timeline without regard to start, completion, or duration times. It is in this exercise where the project planner lists all of the steps required to complete a project. This task list should be detailed as highly as possible to enable the project manager to follow the plan with ease.

The desired detail is determined by the requirements of the project. Some projects require week-by-week detail; other projects require that all resource movements be planned. It is also useful to schedule design reviews and re-engineering time if a design or component does not meet initial specifications as set out at project inception. Testing of designs or component parts should also be scheduled.

The second step in timeline drawing is the assignment of task duration. The project planner assigns time duration to each task, usually in increments of days or fractions thereof. If, for example, a task is the manufacturing of a PC Board (without soldering of components), the planner may assign a half-day to that task. All durations are assigned without regard to linking.

The next step is task linking. Here the planner determines the order in which tasks must be completed. Microsoft Project allows linking with simple keyboard commands. The planner links all tasks together with a final completion date being noted. It is in this step where the planner must make certain decisions in order to schedule a satisfactory completion date. Tasks may be altered with respect to their duration or scheduled as concurrent items. The critical path is also delineated during the linking exercise. Once a satisfactory completion date has been scheduled due to these alterations, the planner can publish his or her timeline and proceed to follow the work plan.

Weekly Schedule

Weekly activities in Design I consist of lectures, student presentations and a team meeting with the instructor. Technical and non-technical issues that impact the design project are discussed during team meetings. Students also meet with clients and coordinators at scheduled times to report on progress.

Each student is expected to provide an oral progress report on his or her activity at the weekly team meeting with the instructor, and record weekly progress in a bound notebook as well as on the web site. Weekly report structure for the web page includes: project identity, work completed during the past week, current work within the last day, future work, status review, and at least one graphic. The client and coordinator use the web reports to keep up with the project so that they can provide input on the progress. Weekly activities in Design II include team meetings with the course instructor, oral and written progress reports, and construction of the project. As before, the Internet is used to report project progress and communicate with the sponsors. For the past two years, the student projects have been presented at the annual Northeast Biomedical Engineering Conference.

Other Engineering Design Experiences

Experiences at other universities participating in this NSF program combine many of the design program elements presented here. Still, each university's program is unique. In addition to the design process elements already described, the program at the State University of New York at Buffalo, under the direction of Dr. Joseph Mollendorf, requires that each student go through the preliminary stages of a patent application. Naturally, projects worthy of a patent application are actually submitted. Thus far, a patent has been issued for a “Four-Limb Exercising Attachment for Wheelchairs” and another patent has been allowed for a “Cervical Orthosis.”

CHAPTER 3
MEANINGFUL ASSESSMENT OF DESIGN EXPERIENCES

Brooke Hallowell

The Accrediting Board for Engineering and Technology (ABET)[14] has worked to develop increasingly outcomes-focused standards for engineering education. This chapter is offered as an introduction to the ways in which improved foci on educational outcomes may lead to: (1) improvements in the learning of engineering students, especially those engaged in design projects to aid persons with disabilities, and (2) improved knowledge, design and technology to benefit individuals in need.

Brief History

As part of a movement for greater accountability in higher education, U.S. colleges and universities are experiencing an intensified focus on the assessment of students' educational outcomes. The impetus for outcomes assessment has come most recently from accrediting agencies. All regional accrediting agencies receive their authority by approval from the Council for Higher Education Accreditation (CHEA), which assumed this function from the Council on Recognition of Postsecondary Accreditation (CORPA) in 1996. The inclusion of outcomes assessment standards as part of accreditation by any of these bodies, (such as North Central, Middle States, or Southern Associations of Colleges and Schools, and professional accrediting bodies, including ABET), is mandated by CHEA, and thus is a requirement for all regional as well as professional accreditation. Consequently, candidates for accreditation are required to demonstrate plans for assessing educational outcomes, as well as evidence that assessment results have led to improved teaching and learning and, ultimately, better preparation for beginning professional careers. Accrediting bodies have thus revised criteria standards for accreditation with greater focus on the "output" that students can demonstrate, and less on the "input" they are said to receive.[15]

"Meaningful" Assessment Practices

Because much of the demand for outcomes assessment effort is perceived by instructors as time consuming bureaucratic chore, there is a tendency for many faculty members to avoid exploration of effective assessment practices. Likewise, many directors of academic departments engage in outcomes assessment primarily so that they may submit assessment documentation to meet bureaucratic requirements. Thus, there is a tendency in many academic units to engage in assessment practices that are not truly "meaningful".

Although what constitutes an "ideal" outcomes assessment program is largely dependent on the particular program and institution in which that program is to be implemented, there are at least some generalities we might make about what constitutes a "meaningful" program. For example:

> An outcomes assessment program perceived by faculty and administrators as an imposition of bureaucratic control over what they do, remote from any practical implications... would not be considered "meaningful." Meaningful

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14 Accrediting Board for Engineering and Technology. Criteria for Accrediting Engineering Programs 2010-2011. ABET: Baltimore, MD.

15 Hallowell, B. & Lund, N. (1998). Fostering program improvements through a focus on educational outcomes. In Council of Graduate Programs in Communication Sciences and Disorders, Proceedings of the nineteenth annual conference on graduate education, 32-56.

programs, rather, are designed to enhance our educational missions in specific, practical, measurable ways, with the goals of improving the effectiveness of training and education in our disciplines. They also involve all of a program's faculty and students, not just administrators or designated report writers. Furthermore, the results of meaningful assessment programs are actually used to foster real modifications in a training program.[16]

Outcomes Associated with Engineering Design Projects

Despite the NSF's solid commitment to engineering design project experiences and widespread enthusiasm about this experiential approach to learning and service, there is a lack of documented solid empirical support for the efficacy and validity of design project experiences and the specific aspects of implementing those experiences. Concerted efforts to improve learning, assessment methods and data collection concerning pedagogic efficacy of engineering design project experiences will enhance student learning while benefiting the community of persons with disabilities.

Agreeing on Terms

There is great variability in the terminology used to discuss educational outcomes. How we develop and use assessments matters much more than our agreement on the definitions of each of the terms we might use to talk about assessment issues. However, for the sake of establishing common ground, a few key terms are highlighted here.

Formative and Summative Outcomes

Formative outcomes indices are those that can be used to shape the experiences and learning opportunities of the very students who are being assessed. Some examples are surveys of faculty regarding current students' design involvement, on-site supervisors' evaluations, computer programming proficiency evaluations, and classroom assessment techniques.[17] The results of such assessments may be used to characterize program or instructor strengths and weaknesses, as well as to foster changes in the experiences of those very students who have been assessed.

Summative outcomes measures are those used to characterize programs, college divisions, or even whole institutions by using assessments intended to capture information about the final products of our programs. Examples are student exit surveys, surveys of graduates inquiring about salaries, employment, and job satisfaction, and surveys of employers of our graduates.

The reason the distinction between these two types of assessment is important is that, although formative assessments tend to be the ones that most interest our faculty and students and the ones that drive their daily academic experiences, the outcomes indices on which most administrators focus to monitor institutional quality are those involving summative outcomes. It is important that each academic unit strive for an appropriate mix of both formative and summative assessments.

Cognitive/Affective/Performative Outcome Distinctions

To stimulate our clear articulation of the specific outcomes targeted within any program, it is helpful to have a way to characterize different types of outcomes. Although the exact terms vary from context to context, targeted educational outcomes are commonly characterized as belonging to one of three domains: cognitive, affective, and performative. Cognitive outcomes are those relating to intellectual mastery, or mastery of knowledge in specific topic areas. Most of our course-specific objectives relating to a specific knowledge base fall into this category. Performance outcomes are those relating to a student's or graduate's accomplishment of a behavioral task. Affective outcomes relate to personal qualities and values that students ideally gain from their experiences during a particular

[16] Hallowell, B. (1996). Innovative Models of Curriculum/Instruction: Measuring Educational Outcomes. In *Council of Graduate Programs in Communication Sciences and Disorders, Proceedings of the Seventeenth Annual Conference on Graduate Education*, 37-44.

[17] Angelo, T. A., & Cross, K. P. (1993). *Classroom assessment techniques: A handbook for college teachers*. San Francisco: Jossey-Bass.

educational/training program. Examples are appreciation of various racial, ethnic, or linguistic backgrounds of individuals, awareness of biasing factors in the design process, and sensitivity to ethical issues and potential conflicts of interest in professional engineering contexts.

The distinction among these three domains of targeted educational outcomes is helpful in highlighting areas of learning that we often proclaim to be important, but that we do not assess very well. Generally, we are better at assessing our targeted outcomes in the cognitive area (for example, with in-class tests and papers) than we are with assessing the affective areas of multicultural sensitivity, appreciation for collaborative teamwork, and ethics. Often, our assessment of performative outcomes is focused primarily on students' design experiences, even though our academic programs often have articulated learning goals in the performative domain that might not apply only to design projects.

Faculty Motivation

A critical step in developing a meaningful educational outcomes program is to address directly pervasive issues of faculty motivation. Faculty resistance is probably due in large part to the perception that outcomes assessment involves the use of educational and psychometric jargon to describe program indices that are not relevant to the everyday activities of faculty members and students. By including faculty, and perhaps student representatives, in discussions of what characterizes a meaningful assessment scheme to match the missions and needs of individual programs we can better ensure a sense of personal identification with assessment goals on the part of the faculty. Also, by agreeing to develop outcomes assessment practices from the bottom up, rather than in response to top-down demands from administrators and accrediting agencies, faculty member skeptics are more likely to engage in assessment efforts.

Additional factors that might give faculty the incentive to get involved in enriching assessment practices include:

- Consideration of outcomes assessment work as part of annual merit reviews,
- Provision of materials, such as sample instruments, or resources, such as internet sites to simplify the assessment instrument design process
- Demonstration of the means by which certain assessments, such as student exit or employer surveys, may be used to make strategic program changes.

These assessment practices may be used to a program's advantage in negotiations with administration (for example, to help justify funds for new equipment, facilities, or salaries for faculty and supervisory positions).[14]

With the recent enhanced focus on educational outcomes in accreditation standards of ABET, and with all regional accrediting agencies in the United States now requiring extensive outcomes assessment plans for all academic units, it is increasingly important that we share assessment ideas and methods among academic programs. It is also important that we ensure that our assessment efforts are truly meaningful, relevant and useful to our students and faculty.

An Invitation to Collaborate in Using Assessment to Improve Design Projects

Readers of this book are invited to join in collaborative efforts to improve student learning, and design products through improved meaningful assessment practices associated with NSF-sponsored design projects to aid persons with disabilities. Future annual publications on the NSF-sponsored engineering design projects to aid persons with disabilities will include input from students, faculty, supervisors, and consumers on ways to enhance associated educational outcomes in specific ways. The editors of this book look forward to input from the engineering education community for dissemination of further information to that end.

ABET's requirements for the engineering design experiences provide direction in areas that are essential to assess in order to monitor the value of engineering design project experiences. For example, the following are considered "fundamental elements" of the design process: "the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation" (p. 11). Furthermore, according to ABET, specific targeted outcomes associated with engineering design projects should include:

- Development of student creativity,
- Use of open-ended problems,
- Development and use of modern design theory and methodology,

- Formulation of design problem statements and specifications,
- Consideration of alternative solutions, feasibility considerations,
- Production processes, concurrent engineering design, and
- Detailed system descriptions.

The accrediting board additionally stipulates that it is essential to include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics, and social impact. ABET's most recent, revised list of similar targeted educational outcomes is presented in the Appendix to this chapter. We encourage educators, students and consumers to consider the following questions:

- Are there outcomes, in addition to those specified by ABET, that we target in our roles as facilitators of design projects?
- Do the design projects of each of the students in NSF-sponsored programs incorporate all of these features?
- How may we best characterize evidence that students engaged in Projects to Aid Persons with Disabilities effectively attain desired outcomes?
- Are there ways in which students' performances within any of these areas might be more validly assessed?
- How might improved formative assessment of students throughout the design experience be used to improve their learning in each of these areas?

Readers interested in addressing such questions are encouraged to send comments to the editors of this book. The editors of this book are particularly interested in disseminating, through future publications, specific assessment instruments that readers find effective in evaluating targeted educational outcomes in NSF-sponsored engineering design projects.

Basic terminology related to pertinent assessment issues was presented earlier in this chapter. Brief descriptions of cognitive, performative, and affective types of outcomes are provided here, along with lists of example types of assessments that might be shared among those involved in engineering design projects.

Cognitive outcomes are those relating to intellectual mastery, or mastery of knowledge in specific topic areas. Some examples of these measures are:

- Comprehensive exams,
- Items embedded in course exams,
- Pre- and post-tests to assess "value added",
- Design portfolios,
- Rubrics for student self-evaluation of learning during a design experience,
- Alumni surveys, and
- Employer surveys.

Performative outcomes are those relating to a student's or graduate's accomplishment of a behavioral task. Some performance measures include:

- Evaluation of graduates' overall design experience,
- Mastery of design procedures or skills expected for all graduates,
- Student evaluation of final designs, or of design components,
- Surveys of faculty regarding student design competence,
- Evaluation of writing samples,
- Evaluation of presentations,
- Evaluation of collaborative learning and team-based approaches,
- Evaluation of problem-based learning,
- Employer surveys, and
- Peer evaluation (e.g., of leadership or group participation).

Affective outcomes relate to personal qualities and values that students ideally gain from their educational experiences. These may include:

- Student journal reviews,
- Supervisors' evaluations of students' interactions with persons with disabilities,
- Evaluations of culturally-sensitive reports,
- Surveys of attitudes or satisfaction with design experiences,
- Interviews with students, and
- Peers', supervisors', and employers' evaluations.

APPENDIX: Desired Educational Outcomes as Articulated in ABET's "Engineering Criteria for the 2011-2012 Academic Year" (Criterion 3, Student Outcomes)[18]

Engineering programs must demonstrate that their graduates have:

(a) an ability to apply knowledge of mathematics, science, and engineering

(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(d) an ability to function on multidisciplinary teams

(e) an ability to identify, formulate, and solve engineering problems

(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(i) a recognition of the need for, and an ability to engage in life-long learning

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

[18] ABET, Engineering Accreditation Commission (2011-12). Criteria for Accrediting Engineering Programs. ABET: Baltimore, MD, p. 3.

CHAPTER 4
USING NSF-SPONSORED PROJECTS TO ENRICH STUDENTS' WRITTEN COMMUNICATION SKILLS

Brooke Hallowell

Based on numerous anecdotes offered inside and outside of engineering, age-old stereotypes that engineers lack communication skills may have some basis in fact. However, current work environments for most new graduates in a host of professional biomedical engineering contexts, place such heavy expectations for, and demands on, excellence in oral and written communication that engineers' lack of communication skills can no longer be tolerated as a trade-off for their strengths in science and mathematics. Evolving requirements for communication with interdisciplinary team members, clients, patients, consumers, employers, and the public require that educators of engineers work hard to ensure that students reach a standard of excellence in communication before they enter the workforce. This chapter is offered to provide specific guidance on principles and resources for enriching written communication skills in biomedical engineering students through their NSF-sponsored design project experiences.

A Formative Focus

As discussed in the previous chapter, a formative focus on academic assessment allows educators to use assessment strategies that directly influence students who are still within their reach. A solid approach to formative assessment of writing skills involves repeated feedback to students throughout educational programs, with faculty collaboration in reinforcing expectations for written work, use of specific and effective writing evaluation criteria, and means of enhancing outcomes deemed important for regional and ABET accreditation. Given that most students in the NSF-sponsored Senior Design Projects to Aid Persons with Disabilities programs are already in their fourth year of college-level study, it is critical to recognize that previous formative writing instruction is essential to their continued development of writing skills during the senior year. Model strategies for improving writing presented here in light of senior design projects may also be implemented at earlier stages of undergraduate learning.

Clarifying Evaluation Criteria

Student learning is directly shaped by how students think they will be assessed. Regardless of the lofty goals of excellence instructors might set forth in course syllabi and lectures, if specific performance criteria are not articulated clearly and assessed directly, then students are unlikely to reach for those same goals. To enhance writing skills effectively through the senior design experience, specific evaluation criteria for writing quality must be established at the start of the senior design experience. Clear expectations should be established for all written work, including related progress reports, web page content, and final reports. Although the examples provided here are oriented toward writing for annual NSF publications, the basic assessment process is ideally applied to other areas of written work as well.

Elements of Writing to be Assessed

What aspects of writing quality are important in writing about senior design projects? The list of specific ideal aspects varies among instructors. Still, consideration of guidelines already proposed may help to streamline the development of finely tuned assessment instruments to shape and evaluate student writing. Each year, the editors of this annual publication on senior design projects send guidelines for manuscript publication to principal investigators on NSF-sponsored Engineering Senior Design Projects to Aid Persons with Disabilities grants.

Those guidelines form the basis for the elements of writing on which writing projects may be evaluated.

A sample grading form, based on the most recent version of those guidelines at the time of this publication, may be found in Appendix A. Explicit writing criteria are specified, and a means for explicit scoring according to those criteria is provided. Instructors may use such a form to evaluate drafts and final project reports. Specific item descriptions and the relative weighting of the value of performance in specific areas may be modified according to instructor preferences. Application of such scoring systems to student course grades will ensure greater student accountability for meeting explicit writing standards.

General categories for analyzing writing performance for project reports include: 1) form and formatting, 2) accompanying images, 3) grammar, spelling, punctuation, and style, 4) overall content, and 5) content within specific sections.

Form and formatting concerns are related primarily to students following of explicit instructions regarding page limitation, spacing, margins, font size, indentations, and headings. Items related to images include the type, quality, relevance and formatting of photographs and drawings used to illustrate reports. Issues of grammar, spelling, punctuation, and style may be largely addressed through adherence to specific conventions for each of these areas. Thorough proofreading and use of computerized checks for spelling and grammar, although frequently recommended by instructors, are not as likely to be carried out by students who are not expecting to be assessed for performance in these important areas.

Areas of overall content evaluation for senior design reports include aspects of writing that are often among the most problematic for undergraduate engineers. One such area is that of using appropriate language when referring to individuals with disabilities. Reports submitted for NSF publications often include terms and descriptions that may be considered offensive by many, such that the editors of this annual publication often engage in extensive rewriting of sections including client descriptions. It is most likely that students engaged in projects for persons with disabilities are wholeheartedly supportive of their clients, and use such terms out of naiveté rather than any ill intent. Still, the words we use to communicate about other people powerfully influences readers' perceptions of them, especially in cases in which readers may be unfamiliar with the types of conditions those people are experiencing. Using appropriate language is of paramount importance to our joint mission of enabling individuals to live fully and with maximum independence. It is thus critical that instructors provide clear instruction and modeling for appropriate language use in writing about disabilities. In cases where instructors may have outdated training concerning language use in this arena, it is critical that they seek training regarding sensitivity in language use.

Basic guidelines for writing with sensitivity about persons with disabilities are summarized briefly in Appendix B. Using person-first language, avoiding language that suggests that individuals with disabilities are "victims" or "sufferers", and avoiding words with negative connotations are three key components to appropriate language use.

Evaluation of content within specific sections of senior design project reports will help students focus on drafting, appropriately revising and editing reports. By discussing and evaluating specific criteria - such as the use of laypersons' terms in a project description, effective description of the motivation for a particular design approach, and the use of clear, concise technical language to describe a device modification such that others would be able to replicate the design - instructors may help students further hone their writing and revision skills.

A Hierarchy of Revision Levels

Constructive feedback through multiple revisions of written work is critical to the development of writing excellence. Even for the accomplished writer, a series of drafts with a progressive evolution toward a polished product is essential. It is thus important that instructors allow time for revision phases for all writing assignments throughout the senior design experience.

Three basic levels of writing revision proposed by some authors include global, organizational, and polishing revision[19]. Global revision involves a general overhaul of a document. Macro-level feedback to students about their general flow of ideas and adherence to assignment guidelines helps to shape an initially-submitted draft into a version more suitable for organizational revision. Organizational revision requires reshaping and reworking of the text. Helpful feedback to students at this level may involve revising of macro-level issues not corrected since the initial draft, and/or a focus on new micro-level issues of coherence, clarity, relevance, and word choice. Polishing revision entails attention to such flaws as grammatical errors, misspellings, misuse of punctuation, and specific formatting rules for the assignment. Finding patterns of errors and providing constructive feedback about those patterns may help individuals or teams of students learn efficient strategies for improving their written work.

Structured Critical Peer Evaluation

Many instructors require several forms of written assignments within project design courses, including the final reports required for submission to the NSF-sponsored annual publication. Consequently, it is impractical or impossible for many instructors to provide evaluation and feedback at three levels of revision for each written assignment. One means of promoting students' experience with critical reflection on writing is to implement assignments of structured critical evaluation of writing using reader-response strategies, with students as editors for other students' work. Students (as individuals or on teams) may be given a basic or detailed rubric for evaluating other students' written work, and explicit guidelines for providing structured constructive comments following critical evaluation.

Resources and Support

Numerous excellent texts are available to promote and provide structure and guidance for the development of essential writing skills in engineering students. Some sample recommended texts are listed in Appendix C. Comments and suggestions from instructors, who have developed model writing programs for engineering design courses at any level of study, are welcome to submit those to the editors of this book, to be considered for future publication.

[19] Ohio University Center for Writing Excellence Teaching Handouts [on-line] (2007). Available at: http://www.ohio.edu/writing/tr1.cfm

APPENDIX A: Sample Evaluation Form for Project Reports Prepared for Annual NSF Publications on Senior Design Projects to Aid Persons with Disabilities

Item evaluated	**Score/ Possible Score**
A. Form and formatting	
Does not exceed two pages (unless authorized by instructor)	/2
10-point type size throughout the manuscript	/2
Margin settings: top =1", bottom=1", right=1", and left=1"	/2
Title limited to 50 characters on each line (if longer than 50 characters, then skips two lines and continues, with a blank line between title text lines)	/1
Text single spaced	/2
No indenting of paragraphs	/1
Blank line inserted between paragraphs	/1
Identifying information includes: project title, student name, name of client coordinator(s), supervising professor(s), university address	/2
Appropriate headings provided for Introduction, Summary of impact, and Technical description sections	/2
Total points for form and formatting	**/15**
B. Images	
Photographs in black and white, not color	/1
Photographs are hard copies of photo prints, not digital	/1
Line art done with a laser printer or drawn professionally by pen with India (black) ink	/2
Images clearly complement the written report content	/2
Photographs or line art attached to report by paperclip	/1
Photographs or line art numbered on back to accompany report	/1
Figure headings inserted within the text with title capitalization, excluding words such as “drawing of” or “photograph of”	/2
Total points for images	**/10**

C. Grammar, spelling, punctuation, and style	
Consistent tenses throughout each section of the report	/2
Grammatical accuracy, including appropriate subject-verb agreement	/2
Spelling accuracy	/2
Appropriate punctuation	/2
Abbreviations and symbols used consistently throughout (For example, " or in. throughout for "inch;" excludes apostrophe for plural on abbreviations, such as "BMEs" or "PCs"	/2
Uses the word "or" rather than a slash (/) (For example, "He or she can do it without assistance.")	/1
Numbers one through 9 spelled out in text; number representations for 10 and higher presented in digit form (except in series of numbers below and above 10, or in measurement lists)	/1
In lists, items numbered, with commas between them (for example: "The device was designed to be: 1) safe, 2) lightweight, and 3) reasonably priced.")	/1
Consistent punctuation of enumerated and bulleted lists throughout the report	/2
Total points for grammar, spelling, punctuation, and style	**/15**
D. Overall content	
Excludes extensive tutorials on specific disabilities	/2
Demonstrates appropriate language regarding individuals with disabilities	/3
Avoids redundancy of content among sections	/3
Demonstrates clear and logical flow of ideas	/3
Excludes use of proper names of clients	/3
Citation and reference provided for any direct quote from published material	/1
Total points for overall content	**/15**

E. Section content	
Introduction	
Includes a brief description of the project in laypersons' terms	/4
Includes problem addressed, approach taken, motivation for the approach, a summary of usual or existing solutions, and problems with these solutions	/4
Summary of impact	
Includes a brief description of how this project has improved the quality of life of a person with a disability	/5
Includes a quoted statement from an educational or health care specialist who supervises the client, or from a significant other	/2
Includes a description of the project's usefulness and overall design evaluation	/5
Technical description	
Clear, concise technical description of the device or device modification such that others would be able to replicate the design	/10
Detailed parts lists included only if parts are of such a special nature that the project could not be fabricated without the exact identity of the part	/2
Text refers to circuit and/or mechanical drawing of the device	/3
Includes analysis of design effectiveness	/5
Concludes with approximate cost of the project, including parts and supplies (not just the NSF's contribution) and excluding personnel costs	/5
Total points for section content	**/45**

Evaluation Summary

A. Total points for form and formatting	**/15**
B. Total points for images	**/10**
C. Total points for grammar, spelling, punctuation, style	**/15**
D. Total points for overall content	**/15**
E. Total points for section content	**/45**
TOTAL POINTS	**/100**

APPENDIX B: A Summary of Guidelines for Writing about Persons with Disabilities

The World Health Organization (WHO) has launched world-wide efforts to modify the ways in which we refer to persons with disabilities. The WHO emphasizes that disablement is not considered an attribute of an individual, but rather the complex interactions of conditions involving a person in the context of his or her social environment. An early classification scheme proposed by the WHO, the International Classification of Impairments, Disabilities and Handicaps (ICIDH) employs the general terms "impairment", "disability", and "handicap"; a more recent scheme, the ICIDH-2, employs the terms "impairment", "activity", and "participation"; the most recent version, the International Classification of Functioning, Disability and Health (ICF), suggests that body functions and structures, activities and participation should refer to the various contextual aspects of disabling conditions one might experience.[20] Healthcare professionals and researchers throughout the world are following suit by de-emphasizing the reference to individuals according to medically-based diagnostic categories, focusing instead on their holistic functional concerns and what might be done to address them. Readers of this book are encouraged to join in this important movement. General guidelines are presented here.

Recognize the importance of currency and context in referring to individuals with disabilities

There are always variances in the terms that particular consumers or readers prefer, and it is essential to keep current regarding changes in accepted terminology.

Refer to "disabilities"

Although the very term "disability" may be considered offensive to some (with its inherent focus on a lack of ability), it is currently preferred over the term "handicap" in reference to persons with physical, cognitive, and/or psychological challenges or "disabilities".

Use person-first language

Person-first language helps emphasize the importance of the individuals mentioned rather than their disabilities. For example, it is appropriate to refer to a "person with a disability" instead of "disabled person," and to say "a child with cerebral palsy" instead of "a cerebral palsied child.

Avoid using condition labels as nouns

Many words conveying information about specific disabilities exist in both noun and adjectival forms, yet should primarily be used only as adjectives, or even better, modified into nouns corresponding to conditions, as in the person-first language examples given above. For example, it is not appropriate to call an individual with aphasia "an aphasic." Although the term "an aphasic individual" would be preferred to the use of "an aphasic" as a noun, such labeling may convey a lack of respect for, and sensitivity toward, individuals who have aphasia.[21] A more appropriate term would be "person with aphasia." Likewise, it is not appropriate to call an individual with paraplegia "a paraplegic," or to call persons with disabilities "the disabled."

Avoid Language of Victimization

Do not use language suggesting that clients are "victims" or people who "suffer" from various forms of disability. For example, say, "the client had a stroke" rather than "the client is a stroke victim." Say, "She uses a wheelchair," rather than "she is confined to a wheelchair." Say "her leg was amputated…" instead of, "the client suffered an amputation of the leg."

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20 World Health Organization (2007). International Classification of Functioning, Disability and Health (ICF) [on-line]. Available: http://www.who.int/classifications/icf/en/

21 Brookshire, R.H. (1992). An introduction to neurogenic communications disorders. St. Louis: Mosby – Year Book.

Avoid words with negative connotations

Words that evoke derogatory connotations should be avoided. These include such words and phrases as affliction, crazy, crippled, defective, deformed, dumb, insane, invalid, lame, maimed, mute, retard, and withered.

Encourage others in appropriate language use

By modeling appropriate language in writing about persons with disabilities, authors take an important step in helping others to improve in this area. It is also important to help others learn to implement guidelines such as these directly through course work and other educational experiences. Likewise, polite and constructive corrections of others using inaccurate language helps encourage more positive communication as well as more enabling positive societal attitudes, widening the arena for empowering persons with disabilities.

CHAPTER 5

CONNECTING STUDENTS WITH PERSONS WHO HAVE DISABILITIES

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INTRODUCTION

For many students, participation in the National Science Foundation (NSF) projects to aid persons with disabilities is a unique experience. Often it is their first opportunity to work with individuals with disabilities. As such, not only must they meet the academic requirements of their senior design project, but in order to be successful, they must also learn about disabilities and related issues. Only when students are able to combine their scientific knowledge with an understanding of other related humanistic factors will they be able to make significant contributions to the field. Therefore, it is imperative for engineering programs participating in the NSF projects to ensure that students have the opportunity to gain the necessary awareness and social competencies needed. Specifically, students need to have a basic understanding of philosophical attitudes toward disability as well as an understanding of assistive technology and how to communicate effectively with persons with

[22] Portions of "The Engineering Perspective" were presented at the 40th Annual Rocky Mountain Bioengineering Symposium, April 2003, Biloxi, MS (Barrett, 2003)

disabilities. This awareness and understanding will not only enable students to have a more meaningful experience, but also ensure a more meaningful experience for the individuals with whom they will be working.

Students must also understand the engineering aspects of their project. The engineering aspects may be viewed from two different levels: the programmatic aspects of the project and the engineering details of their specific project. At the program level, projects must be properly scoped for difficulty and required expertise. At the individual project level the projects must meet specific requirements but also must be safe and reliable. Senior design faculty as well as participating students have the joint responsibility of ensuring that these engineering aspects are met.

In this chapter we will discuss these diverse yet related aspects of National Science Foundation engineering senior design projects to aid persons with disabilities. We will first examine the social constructs of disability, followed by the proper language of disability. We will then investigate assistive technology and universal design principles. This chapter will conclude with a discussion of the engineering aspects for a successful design experience.

Models of Disability

There are three predominant social constructs of disability. These models define the source or problem of disability and determines the ways to best address the related issues. The oldest model is the moral model, which posits that disability is caused by moral lapse or sin. It explains disability as a supernatural phenomenon or act of god that serves as punishment and represents the consequences of perceived wrongdoing. It brings shame to the individual and in cultures that emphasize family and/or groups over the individual, the shame spreads to the family and/or group. The person or family carries the blame for causing the disability. In a tenuously more auspicious interpretation of the moral model, disability is perceived as a test of faith (i.e. "God only gives us what we can bear") or as a mystical experience in which one sense may be impaired but others are heightened and the adversity of the disability provides increased emotional and spiritual strength often recognized by the belief that "with the grace of God" the disability can be overcome.

Given the limitations of the moral model, the medical model began to emerge in the mid- 1800s as a result of developing science and improved humanistic medicine. In this model, disability is recognized as a medical problem that resides within the individual. It is a dysfunction, defect, or abnormality that needs to be fixed. The ambition is to restore normality and cure the individual. It is a paternalistic model that expects an individual to assume the role of a victim or sick person and avail themselves to medical professionals and services. The individual is a passive participant. However, as medicine and professionals have advanced in their knowledge and understanding, this model has given way to a more person-centered version, often referred to as the rehabilitation model, in which disability is analyzed in terms of function and limitations. In this paradigm, a more holistic approach is taken. The individual is a more active participant and his or her goals are the basis for therapeutic intervention. The emphasis is on functioning within one's environments. A variety of factors are assessed in terms of barriers and facilitators to increased functioning. This model recognizes disability as the corollary of interaction between the individual and the environment. The individual is recognized as a client and the emphasis is based on assisting the individual in adjusting or adapting. It is important to note that, although this model derives from a systems approach, the primary issues of disability are still attributed to the individual.

In the last 30 years, another model has emerged: the social model of disability, which is also referred to as a minority group model and/or independent living model. Its genesis resides within the disability rights movement and proclaims that disability is a social construction. Specifically, the problem of disability is not within the individual, but within the environment and systems with which the individual must interact. The barriers that prevent individuals with disabilities from participating fully and equally within society include prejudice, discrimination, inaccessible environments, inadequate support, and economic dependence.

While it is beyond the scope of this chapter to view these constructs in detail, an awareness of these models enables one to examine one's own beliefs and attitudes toward disability. It also helps students understand that they will encounter both professionals and persons with disabilities whose beliefs are rooted in any one (or combination of) these identified constructs. Although it may not be readily evident, these beliefs will impact how students approach their projects, their ability to see beyond the disability and consider other related factors, and their ability to establish meaningful relationships with the individuals they are trying to assist. Therefore, it is highly recommended that all engineering programs establish collaborative partnerships with other disability professionals in order to provide students with an awareness of disability issues. Potential partners include other programs within the university, especially those with disability studies programs, state assistive technology projects, and independent living centers.

Language of Disability

Terminology and phrases used to describe many people (those with and without disabilities) have changed over time. Many words and phrases are embedded in the social constructs and ideologies of our history and the changes in terminology reflect the paradigm shifts that have occurred over time. For example, the terms Native American or African American have changed with the Zeitgeist and no longer reflect the often derogatory words or phrases that preceded them. Although there is often disdain for those that advocate political correctness, it is important to realize that words and expressions can be powerful and that they do, in fact, communicate attitudes, perceptions, feelings, and stereotypes. They can be oppressive or empowering. The changes in language that have occurred represent an acceptance of diversity and a respect for differences which ultimately impact social change. As professionals and educators, we are in fact, agents of change, and it is our responsibility to recognize the power of language and to use it befittingly in our conversations, discussions and writings.

In regard to disability, the use of person first language (i.e. always putting the person before the disability) recognizes the person first and foremost as a unique individual. In contrast, referring to someone by his or her disability defines them by a single attribute and limits the ability to distinguish who they are as a person from the disability, which in fact they may consider to be a very minute characteristic. For example, the statement "The stroke victim's name is Joe" conjures up a very different image from "Joe is a great musician who had a stroke last year", or "she can't ski; she is paralyzed and confined to a wheelchair" versus "she loves to ski and uses a sit ski device because she has paraplegia and is a wheelchair user." Putting the person before the disability demonstrates respect and acknowledges the person for who he or she is, not for what he or she does or does not have. Although it may seem awkward when one first begins to use person first language, it will become natural over time, it will demonstrate respect, and it will have a positive societal impact. For guidelines on person-first language, a keyword internet search will reveal many resources. For detailed guidelines on writing, see Chapter 4.

Assistive Technology and Universal Design

Assistive Technology (AT) is a general term that describes any piece of equipment or device that may be used by a person with a disability to perform specific tasks and to improve or maintain functional capabilities, thus providing a greater degree of independence, inclusion, and/or community integration. It can help redefine what is possible for people with a wide range of cognitive, physical, or sensory disabilities. AT can be simple or complex. It can include off-the-shelf items as well as special designs. Devices become AT through their application. This technology may range from very low-cost, low-tech adaptations (such as a battery interrupter to make a toy switch accessible) to high-tech, very expensive devices (such as a powered mobility equipment and environmental controllers).

AT can include cognitive aids, aids to assist with walking, dressing, and other activities of daily living, aids to augment hearing or vision, adaptive recreation devices, augmentative communication aids, and alternate computer access. Services related to Assistive Technology may include evaluation for appropriate equipment and systems, assistance with purchasing or leasing devices, and selecting, defining, fitting, adapting, applying, maintaining, repairing, or replacing equipment and systems. In addition, services could include training and technical assistance for individuals and their families, and/or other professionals. Assistive Technology may be used at home, in the workplace, in the classroom and in the community to provide creative solutions in assisting individuals as they go about their activities of living, learning, working, and playing.

Universal Design (UD) refers to a concept or philosophy for designing and delivering products and services that are usable by people with the widest possible range of functional capabilities. This includes products and services that are directly usable (without requiring assistive technology) and products and services that are made usable with assistive technology.

As noted earlier, the social model of disability focuses on the environment as the most significant barrier preventing people with disabilities from full contribution to all aspects of society. As such, the concepts of universal design have significant potential for remedy (see reference section for resources specific to universal design). The basic premise of universal design is to create access, in terms of the mass marketplace as well as community and information environments, for as many people as possible, regardless of age, size, or ability.

It is estimated that approximately thirty million people have a disability or functional limitation due to injury, illness or aging (Vanderheidin, 1990). With the advances in modern medicine and the emerging inroads in health promotion and disease prevention, people are living longer. Nearly everyone will experience some type of functional limitation during the course of a lifetime. Given such broad prevalence of disability in the general population, the need for universal design becomes self-evident.

The underlying principles of universal design (UD) are available for review at www.design.ncsu.edu, The Center for Universal Design, North Carolina State University. These basic principles provide the philosophical interface between functional limitations/disability and best practices in design. In fact, universal design principles can often simplify the adaptation or even eliminate the need for specialized design created specifically for the individual person. Conversely, when prototype devices are necessary, if they adhere to principles of UD, it is much more likely that the device will also be able to be adopted by others and that the technology will be able to be transferred to other applications. When assistive technology is necessary to support access and/or use of the built environment, products, or information, the understanding that any design must first and foremost respect personal dignity and enhance independence without stigmatizing the individual is critical. This is clearly a quality of life issue for everyone. Working with an individual who has disabilities to develop assistive technology requires the engineer to actively collaborate, respecting the right of each person to self-determination and self-control (Shapiro, 1993).

In general, the areas of functional limitation most amenable to benefit from the concepts of universal design (and assistive technology where necessary) are in the broad categories of: communication, mobility, sensory, manipulation, memory, and cognition. All design should consider and address varying human abilities across each of these domains. The goal of universal design is to eliminate, as much as possible, the need for assistive technologies because the focus of all design is inclusive rather than restrictive. Historically, designs were often based on the young, able-bodied male. With the advent of UD, designers are redefining the user to include as many people as possible with the widest range of abilities.

There are many examples of how assistive technologies have been adopted by the general population. For example, at one time the use of closed captioning was limited to individuals who were hard of hearing or deaf. Today, captioning can be seen on televisions located in public places such as restaurants, airports, and sports bars. Captioning is also used by many people in their own homes when one person wishes to watch TV while another does not. Other examples include ramps, curb cuts and automatic door openers. Initially designed for individuals who were wheelchair users, it was quickly realized they also benefited delivery personnel, people with strollers, people with temporary injuries, cyclists, etc. In addition, many items related to computer access such as voice recognition, are now employed in a variety of computer and telecommunication applications. When UD principles are employed, the whole environment, in the broadest sense becomes more humane and maximizes the potential contribution of everyone, not just those with disabilities.

As senior design students explore their options for projects, an awareness of disability issues, existing assistive technologies and universal design principles will ensure that their projects incorporate state-of-the-art practices. A list of valuable resources is included at the end of this chapter.

The Engineering Perspective

To provide for a successful Engineering Senior Design Projects to Aid Persons with Disabilities Program, projects must be successful at both the program level and the individual project level. In this section we discuss aspects of a successful program and use the University of Wyoming's program as a case study.

To be successful at the academic program level, a program must successfully address the following aspects:

- Provide a team approach between assistive technology professionals and engineering participants,
- Receive appropriate publicity within assistive technology channels,
- Provide projects that have been properly scoped for difficulty, student team size, and required student expertise, and
- Have mechanisms in place to address the safety aspects of each project and the legal aspects of the program.

To address these needs, the College of Engineering partnered with four other programs to identify the specific needs of the individual. Specifically, the college joined with the Wyoming Institute for Disabilities (WIND) assistive technology program, Wyoming New Options in Technology (WYNOT) (including their Sports and Outdoor Assistive Recreation (SOAR) project) and the university's special education program.

With this assembled team of professionals, specific duties were assigned to the team members. The WYNOT Project Director served as the coordinator with the community to identify specific assistive technology needs. This was accomplished using a short project application to identify the desired assistive device and the special needs of the individual. Project proposals were initiated by the individual with a disability, his or her family members, caregivers, or teachers, or any of the service agencies in the state of Wyoming. WYNOT was also the key player in the promotion of the Biomedical Engineering Program and Research to Aid Persons with Disabilities (BME/RAPD). Marketing included featured articles in the WYNOT newsletter, posting of project information on the WYNOT website, development of a project website (http://wwweng.uwyo.edu/electrical/faculty/barrett/assist/), public service announcements, and statewide and nationwide press releases.

The WYNOT project director and the engineering PI met on a regular basis to evaluate the suitability of the submitted projects. Specifically, each requested project was reviewed to ensure it was sufficiently challenging for a year-long senior design project. Also, the required engineering expertise was scoped for each project. Once a project was determined to be of suitable scope for an undergraduate design project, the PI coordinated with the appropriate engineering department(s) to publicize the project in the senior design course. This process is illustrated in Fig. 5.1. Overall, an individual with a disability was linked with a student engineering team, which was to provide a prototype custom designed assistive device specific to his or her needs.

Since these projects involve the use of human subjects, students were required to complete an Institutional Review Board (IRB) study prior to initiating a specific project. These studies were completed and submitted to the IRB per federal and university guidelines. Furthermore, projects were delivered to the recipients only after extensive testing. At that time the recipient or his or her legal guardian signed a “Hold Harmless” agreement. This agreement was reviewed and approved by the university’s legal office.

At the individual project level, students must:

- Be educated on assistive technology awareness,
- Be committed to delivering a completed, quality project,
- Be aware of available expertise to assist with the technical aspects of the project,
- Work closely with the individual who will be using the project, and
- Provide adequate time in the project schedule for testing and remanufacture if required.

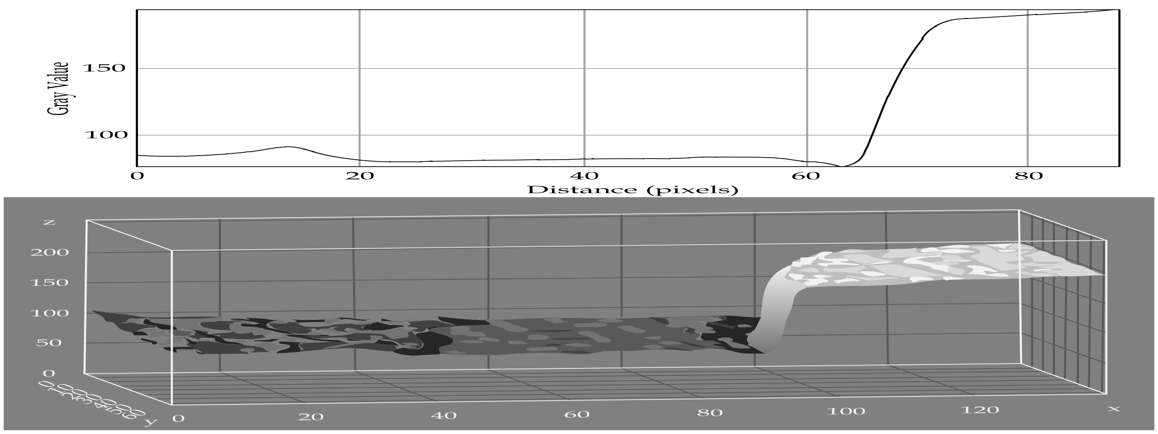

Fig. 5.1. Program Flow for Undergraduate Design Projects to Aid Wyoming Persons with Disabilities (Barrett, 2003).

To assist the students in developing these aspects of the project, the PI met with each senior design course at the beginning of the semester. The PI reviewed the purpose of the program, described potential projects, and also emphasized the importance of delivering a completed project. Students were encouraged to meet individually with the PI if they wanted more information about a specific project. At these follow-up meetings, the students were given all available information about the project and a point of contact to obtain more information from the requesting assistive technology agency or individual. Students were encouraged to contact these individuals to begin developing a relationship between the project user and designer.

Many of the projects were interdisciplinary in nature typically involving both mechanical and electrical engineering students. Faculty advisors for the senior design courses set up several "get acquainted" sessions at the local pizza parlor for students to get to know each other and also to review potential projects.

WYNOT also provided training to the engineering students regarding assistive devices and services. This training was provided to all students in the senior design course regardless if they were participating in the assistive technology program. This provided disability awareness to the state's next generation of engineers.

Expected Benefits

It is a challenge to get a program of this type initiated; however, the potential benefits far outweigh these challenges. Here is a list of potential benefits:

- Provide engineering students multi-disciplinary, meaningful, community service design projects,
- Provide persons with disabilities assistive devices to empower them to achieve the maximum individual growth and development and afford them the opportunity to participate in all aspects of life as they choose,
- Provide engineering students education and awareness on the special needs and challenges of persons with disabilities, and
- Provide undergraduate engineering students exposure to the biomedical field of engineering.

This quote from a student who participated in the program best sums up the expected benefit:
"As an undergraduate student in the college of engineering, this project personally affected my life in many ways. It not only challenged me to think creatively and to be able to come up with an original design, but it also allowed me to see at a young age how the work I do can better other lives. I am proud to have been a part of this project and to know that something that I helped design and build is allowing people from around the state of Wyoming to be educated about disabilities (Barnes, 2003)."

Resources

Resources on Disability:

The Family Village is a website maintained by the Waisman Center at the University of Wisconsin-Madison,

http://www.familyvillage.wisc.edu/index.htmlx

The Library section allows individuals to search for specific diagnoses or general information on numerous disabilities.

The ILRU (Independent Living Research Utilization) http://www.ilru.org/ilru.html program is a national center for information, training, research, and technical assistance in independent living. The directory link provides contact information for all Independent Living Centers in the country and US territories.

Resources on Assistive Technology:

The National Institute on Disability Rehabilitation and Research,

http://www.ed.gov/offices/OSERS/NIDRR/

funds the state Assistive Technology projects as well as Rehabilitation Engineering Research Centers (RERC). The state projects are excellent resources on a variety of AT issues and the RERC's conduct programs of advanced research of an engineering or technical nature in order to develop and test new engineering solutions to problems of disability. Information on these centers is available through the NIDRR website by searching their project directory for Rehabilitation Engineering Research Centers. These centers specialize in a variety of areas including mobility, communication, hearing, vision, spinal cord injury, recreation, prosthetics and orthotics, and wireless technologies to name just a few. These are excellent resources to learn more on state-of-the-art engineering projects to assist individuals with disabilities.

Another valuable source is the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) http://www.resna.org/. This is a transdisciplinary organization that promotes research, development, education, advocacy, and the provision of technology for individuals with disabilities. In addition, by using the technical assistance project link on the home page, one can locate all of the state assistive technology projects and obtain contact information for his or her particular state or territory.

For specific product information, http://www.assistivetech.net/ as well as http://www.abledata.com/Site_2/welcome.htm are excellent resources.

Resources on Universal Design:

The Center for Universal Design, North Carolina State University, http://www.design.ncsu.edu/cud.

The Trace Research and Development Center, University of Wisconsin-Madison, http://www.trace.wisc.edu.

The Center for Inclusive Design and Environmental Access (IDEA), University at Buffalo, New York, www.ap.buffalo.edu/idea.

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CHAPTER 6
CALIFORNIA POLYTECHNIC STATE UNIVERSITY

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POP-A-WHEELIE (WHEELCHAIR DANCING)

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INTRODUCTION

Break the Barriers is a non-profit organization founded in October of 1985 by Deby Hergenrader and her husband, Steve. Deby is a skilled and decorated gymnast, who was inspired by her sister with Down' syndrome, to create an organization to give persons with disabilities an opportunity to participate in gymnastic based activities including team dance performances. Break the Barrier's mission is to provide and promote Inclusion-Ability awareness and outreach education worldwide through the touring of their performance teams. They practice in a 39,000 square foot International Ability Center including an adaptive swimming pool, performing arts stage, adaptive basketball court and more. The goal of the Pop-A-Wheelie project is to provide the wheelchair dancers on the Break the Barriers Dance Teams the ability to tilt their chairs backwards and spin during routines. This could be done through the design of a specialized wheelchair attachment that could be deployed by the users during a performance. When designing the attachment, it was necessary to design for the users who have no motor control of their legs. This became the most critical part of the design process because the design required a method of raising the chair back up to the original position for someone who will not be able to use their hips to help lean the chair into position.

SUMMARY OF IMPACT

Break the Barriers (BTB) has been successfully having a huge impact in raising Inclusion-Ability awareness. The Pop-A-Wheelie project adds a new dimension and "wow" factor to the BTB performance teams' shows. The team members have different levels of disability with a few in wheelchairs. The wheelchair teammates can now more actively participate in the performances with their new ability to independently lean back and spin. They will feel more integral to the team as well as proud of their contributions to the overall performance. The team's goal is to inspire those with and without disabilities to do their best and actively participate in their lives. The Pop-A-Wheelie helps them achieve this goal.

TECHNICAL DESCRIPTION

The device consists of two identical arms fitted with caster wheels that can be deployed behind the chair to provide support during the "Pop-a-Wheelie" maneuver. The arms are attached to the standard wheelchairs used by BTB dance teams. When not deployed, the arms are stowed in a vertical position behind the seatback and the caster wheels do not touch the ground.

An important feature of the design is the detent system that is necessary so that the user can push the swing arms back into a 25° angle and hold the rods in that angle so that when the user takes their hands off of the handles, the swing arms stay in place. This was an important aspect to the design since the system must support the user weight and a collapse of the arms at this point might cause the chair to flip over backwards. At the same time, the user needs to be able to release the detent when they want to move back into the upright position. The detent system was designed into the collar assembly as shown in Figure 6. 2.

The assembly consists of two side plates made out of 0.25" thick steel which are bolted to a collar that forms a clamp to go around the wheelchair's support bars. A rubber piece is placed within the hole to ensure the piece is clamped on securely and won't slip when the sidewalls secure it in place. Two steel bars are attached to the sidewalls using screws, which help keep the spring slider within the confines of the collar system. Springs are used to dampen the force caused from tilting backwards. They are compressed against an aluminum support bar. In order to eliminate potential few pinch points, the entire spring assembly is encased inside two sleeves. The spring slider supports the bottom of the springs. As the swing arm swings backward allowing the wheelchair to tilt backward, the slider slides up, compressing the spring. The knob on the side of the slider piece fits into the channel on the sidewall to provide a way for it to slide up and down as the spring compresses and decompresses. The slider is also curved so it remains in contact with the swing arm at all times.

The cost to produce the prototype was $603.17 in materials.

Fig. 6.1. The Designer's "Popping a Wheelie" and a Solid Model of the Final Design.

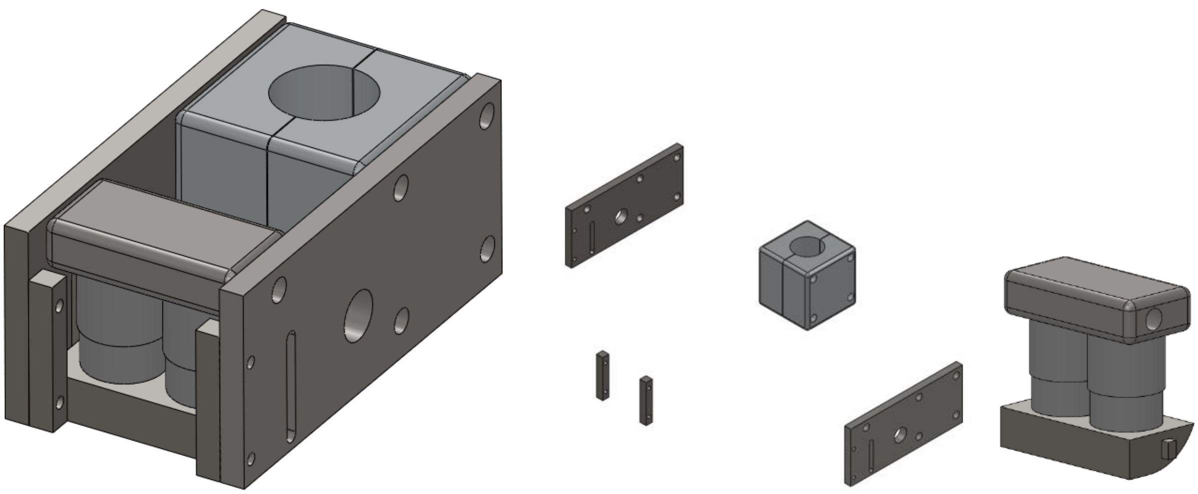

Fig. 6.2. Solid Model of the collar system along with an exploded view and close-up of spring assembly.

UNILATERAL PADDLING DEVICE FOR KAYAKING

Designers: Courtney Sheffield, Derek Brangham, and Geoff Ledbetter
Client Coordinator: Maggie Palchak, Disabled Sports Eastern Sierra, Mammoth, CA
Supervising Professor: Dr. Joseph Mello
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INTRODUCTION

Disabled Sports Eastern Sierra (DSES) is a non-profit organization that offers both summer and winter outdoor activities for people with various disabilities in Mammoth Lakes, California. One of the many challenges, inherent in their mission, is adapting existing sports equipment for the participants. DSES's kayaking program needed an adaptive system to allow participants with unilateral strength to fully participate in the sport. Disabilities such as cerebral palsy can cause hemiparesis, or weakness on one side of the body. Accompanying this is usually a lack of trunk and grip strength, and low endurance. In the kayaking program, DSES pairs each participant with an able-bodied volunteer in a Malibu II tandem kayak. The participant is seated in the bow of the kayak with the better view, and the volunteer controls from the stern, where most of the power is generated. Often, participants with hemiparesis struggle to hold and use the paddle. An important part of any disability adaptation is to preserve the original activity as much as possible. For the project, the device should not be too bulky, motorized, or change the fundamental act of paddling. Safety is also of utmost importance, and capsizing is a real possibility. Therefore, the adaptation should not endanger the participant by entangling them or restricting their movement.

SUMMARY OF IMPACT

Several customer requirements were identified as keys to a successful design. These included:

- The device must be compatible with the Malibu II tandem kayak.
- It must be removable from the kayak and cause no damage from its fixture method.

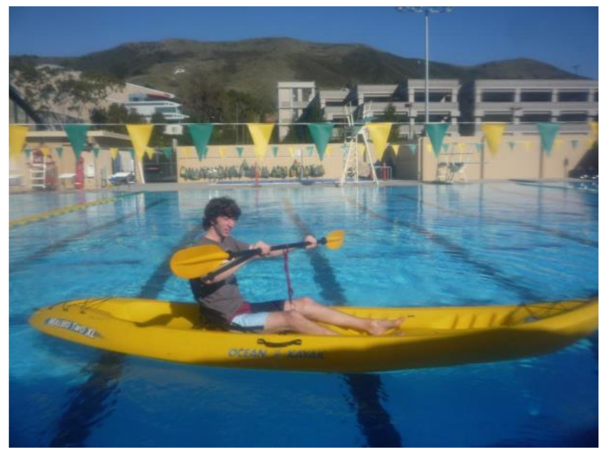

Fig. 6.3. Design Team Measuring height of paddle for different users.

- It must be lightweight, durable, corrosion resistant, and able to withstand a variety of temperatures.
- The paddle itself cannot blister or chafe the user and it must provide grip assistance
- The device must be adaptable to people with hemiparesis in either the left or the right side, require a low force of operation, and must be usable by people of different sizes (children to adults).
- Any strapping must have a quick-release mechanism for safety.
- The device must not utilize a motor for power assistance.

By satisfying these customer requirements, the team was able to design and deliver a working prototype that satisfied the needs of DSES's kayaking program to a high degree. The system can now be used by dozens of participants each summer.

TECHNICAL DESCRIPTION

The unilateral paddling device is attached to the front storage hatch of the kayak using a base of composite fiberglass and carbon fiber in a polyester resin. The fiberglass and carbon cloths were placed in strategic locations to utilize their material properties. Using fiberglass was beneficial due to its low cost, usage in the marine and water sports arenas, and its high modulus of elasticity. The carbon fiber cloth was used for its high stiffness, high strength, and low weight. The storage hatch is about 8 inches in diameter, with a height of 1 inch. It has a small lip around the edge to provide a gripping surface for a rubber lid. The attachment method requires minimal force to install.

Figure 6.4 shows a section view of how the paddling joint attaches to the connecting aluminum piece. Between the two is a plastic thrust bearing to facilitate sliding. The joint itself is separated into two pieces, a base and a top, and was made from 6061 aluminum. The joint is allowed to spin due to a double shielded 316 stainless steel ½" ball bearing which was press fit into the base. The threaded shaft was affixed by two 316 stainless steel jam nuts to prevent loosening. A plastic thrust bearing was inserted between the bottom jam nut and the surface of the joint. The thrust bearings used are ultra-high molecular weight (UHMW) polyethylene and are made to withstand wet corrosive environments.

The cost to produce the prototype was about $650.00 in materials.

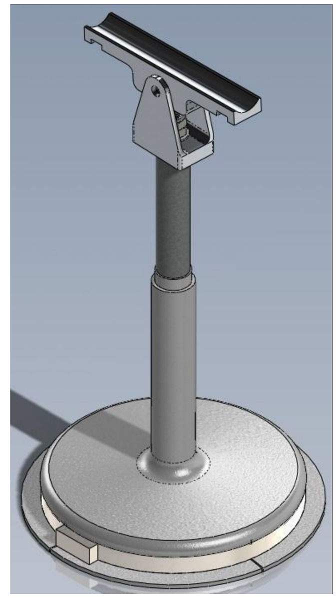

Fig. 6.4. Solid model of the Unilateral Paddling Device and section of the Joint Attachment

POLYCART

Designers: Ryan Bolton, Vincent Contreras, Rodrigo Sanchez
Client Coordinator: Fiona Allen, Bridge II Sports, Durham, NC
Supervising Professor: Sarah Harding
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INTRODUCTION

Many people with disabilities like to stay active by participating in sports and outdoors group activities. Bridge II Sports helps organize sports events for those with disabilities throughout the state of North Carolina. In order to run these events more effectively, an equipment cart was needed to carry the necessary equipment to/from storage areas to the outdoor sport venues. Bridge II Sports strives to make enjoying these physical activities as easy as possible and to promote independence of its clients. The sponsor desired that the cart could be used by their clients with limited mobility, especially those who use a wheelchair. The level of use of the cart includes: transporting the cart with equipment to a possibly remote location over varying terrain, easily accessing the equipment within the cart, loading the cart with equipment and supplies, and finally loading and unloading the cart from the back of a standard minivan. The equipment that the cart will be holding on a regular basis includes equipment for those participating in track and field activities, basketball, golf, gym activities, archery, volleyball, and tennis.

SUMMARY OF IMPACT

The following list of customer requirements was identified as essential to a successful design. These requirements included:

- The cart must fit, either disassembled or complete, in the back of a minivan.
- The cart's internal storage must have minimum dimensions of 3'L x 2'W x 1.5'H in order to accommodate all of the equipment Bridge II Sports uses.
- The cart must weigh no more than 30 pounds in order to be easily pulled, pushed, and loaded and unloaded from the back of a minivan.
- In order to facilitate easy maneuverability, the force required to move the cart will be at most 10 lbs.

Fig. 6.5. Computer Model of the Polycart.

- The cart must not tip over when 15lbs is put on the top edge of the cart.
- The cart needs a parking brake which will provide at least 35 lbs. of stopping force.
- The cart must be able to roll over an obstacle 4 inches in height.

The cart was delivered to Bridge II sports and is used in their daily activities by the participants who now have the ability to bring their own sports equipment to/from the sporting venues independently by pulling the Polycart behind their wheelchairs.

TECHNICAL DESCRIPTION

The design of the Polycart, shown in Figure 6.5, consists of five major subsystems: the cage, the wheel holders, the whiteboard attachment, the steering system, the brake system and the wheelchair attachment system. The cage structure is made of 1 inch square aluminum tubes with 0.065 wall thickness. On the bottom of the cage, there is a tray for storage of miscellaneous items. The tray is equipped with a plastic drawer for easy accessibility. The cage has expanded aluminum on the sides and bottom which adds rigidity to the cart as well as keeping the payload in the cart and not allowing small items to escape. A whiteboard is attached to the back of the cage with a rail system that is attached to the vertical square tubing of the cart. This rail system allows the user to raise and lower and lock the white board in place for better usability and visibility. The rail system also permits the user to completely remove the whiteboard if desired.

Since wheelchair users use different types of wheels whenever they play sports, the regular wheels have to be stored while not in use. The cart is able to hold a total of eight wheels (four sets). The two shorter horizontal bars on the top of the cage have one telescoping round bar that pulls out on each side of the cart. These telescoping bars will be extended to hold the wheelchair wheels, and whenever they are not in use, they can be fully retracted.

The steering system linkage has three pivot points. However, only two are used to maneuver the cart. The third pivot point is used to retract the linkage whenever the cart is not in use, and it only allows movement on a vertical plane. The pivot where the linkage is attached to the cart by a bearing, only allows movement in a horizontal plane. A ball joint allows movement in both vertical and horizontal planes. The ball joint gives flexibility to the clamping mechanism for different height bars on the back of the wheelchair and also allows the cart to be towed across uneven terrain.

The wheelchair attachment method consists of a clamp with grooves to hold the bar that is attached to the wheelchair. The clamp tightens using a cam lever which is quick and easy to use. A cable is attached to the end of the cam lever to allow the user to quickly detach the cart without reaching to the back of the wheelchair. Lastly, the cart is equipped with a parking brake for the front axle to prevent unwanted cart movement. When the cart is attached to a wheel chair and the clamp is secured, there is no tension on the brake cables, and the brakes are disengaged.

The cost to produce the prototype was $1270.00 in materials.

Fig. 6.6. Completed Polycart Undergoing User Testing.

ZEUS THROWING FRAME

Designers: Andrew Higgins, Gabriel Terrasas, and Stefan Owechko
Client: Bridge II Sports
Client Coordinator: Fiona Allen
Supervising Professor: Sarah Harding
Mechanical Engineering and Kinesiology Departments and the School of Education
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INTRODUCTION

The throwing frame was designed to allow individuals with disabilities to perform track and field events without limitation. A throwing frame is an apparatus that individuals with limited mobility in their lower extremities use to participate in throwing events including shot-put, discus, and javelin. The overall goal of the throwing frame project was to build a lighter and stronger throwing frame that could be easily transported and met the rules and regulations established by the Paralympic Games. The throwing frame was designed to be appropriate for as many individuals as possible with a wide range of different disabilities. The throwing frame was built to be used by Bridge II Sports located in North Carolina. The success of the throwing frame at Bridge II Sports will dictate what actions will be taken in the future regarding further manufacturing.

SUMMARY OF IMPACT

The first official Paralympic Games were held in 1960, and since this time several aspects of the games have changed. Adaptations, including throwing frames, were developed to help individuals with limited standing abilities to throw discus, shot-put and javelin. These throwing frames have improved over the course of time, however many are flawed as they do not accommodate for a wide range of disabilities. The Zeus Throwing Frame sought to correct this issue by designing a throwing frame that had various adaptations to facilitate the needs of a larger population. In the Paralympic games, individuals have the option to throw using two methods; one method consists of the individual placing one foot on the ground as they complete their throw and the other method consists of the individual securing both feet to the throwing frame. The Zeus Throwing Frame team successfully designed a frame that allows both methods to be used by simply altering the seat top. This throwing frame design succeeds where

Fig. 6.7. Complete throwing frame.

other have failed, in that it allows a wide range of individuals to utilize the frame. The Zeus Throwing Frame is the ideal throwing frame for an organization

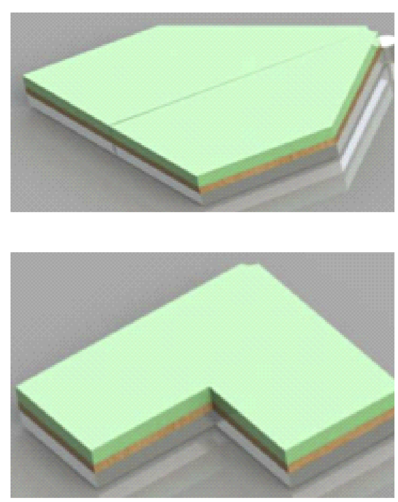

Fig. 6.8. Multi-top “L” and “Home plate” shapes.

that wishes to have a large population of athletes compete with a single frame.

TECHNICAL DESCRIPTION

The completed throwing frame is comprised predominately of aluminum tubing. The aluminum tubing allowed the total weight of the frame to remain light while also providing the necessary strength. The throwing frame was made with telescoping legs so that the height was easily adjustable. There are two different shapes for the seat top, which also allows additional adaptation. The seat top was designed so that it can be removed, change shape and then be reattached. As seen in Figure 6.8, the seat top can be placed in a "Home plate" shape or an "L shape"; these two shapes have the ability to accommodate a greater number of individuals with disabilities. The seat top is capable of changing shape by rotating about a hinge that can sustain a large amount of stress. The throwing frame is fitted with a removable arm bar that was manufactured out of solid 1" aluminum, very capable of withstanding the stress that is applied during a throw.

The total cost to produce this prototype was $1153.85.

Fig. 6.9. Switching the configuration of the seat.

UNTETHERED RUNNING II

Designers: Jason Foulk, Anthony Garcia, Alex Gronbach, Leah Humiston, Trevor Hutton
Supervising Professor: Dr. Lynne A. Slivovsky
Computer Engineering
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San Luis Obispo, CA 93407

INTRODUCTION

The Untethered Running project aims to address the unavailability of products that allow people with visual impairments to practice physical exercise by running. According to the American Foundation for the Blind, approximately ten million people in the United States are blind or visually impaired, and only one percent of that population employs the use of Guide Dogs to increase mobility. The Untethered Team wants to provide another mobility option, specifically for people who want to participate in physical exercise.

Typical methods for blind running often rely on sighted runners; a physical tether, either a rope or bungee system around the waist or finger tethers; or by running alongside a sighted runner and receiving audio cues from them. Counting steps may also be used to accurately cover shorter distances. The goal of the Untethered Running project is to provide a runner with a visual impairment a more autonomous running experience. The Untethered Team hopes to supplement the sensory information for a runner with information regarding position of another (sighted) runner, specifically their distance and the direction, by transmitting information using tactile and audible feedback.

SUMMARY OF IMPACT

The system was designed for a local community member; an avid runner whose running has been affected by the progression of macular degeneration. She has been enthusiastic throughout the development of the project and cannot wait to start running with the system.

TECHNICAL DESCRIPTION

The main components of the project include determining a method to help the runner avoid collisions, alerting the runner of upcoming obstacles or keeping them on course, and remaining nonrestrictive for the user. In conjunction with verbal feedback, all of the pieces work together in unison to track the position of a navigator and assist a runner in their own untethered running on any terrain. The Untethered Running System consists of the following components: Tracking, a Marker t-shirt, and Feedback.

Fig. 6.10. The Untethered Running system tracks a special marker on a runner.

Tracking: The tracking software uses Speeded Up Robust Features (SURF) descriptors, which locate an object by searching the areas of an image that contain corners. Determining the position of the sighted runner (navigator) is done on images captured by a webcam mounted on the front of the visually impaired runner. Computation is done on a BeagleBone computer board.

Marker t-shirt: The selection and development of the t-shirt marker was critical to the success of the project. The team designed a corner-rich marker with contrasting colors. The marker was printed in black ink on a white t-shirt (Figure 6.10). The top box contains two boxes in opposite corners, which make an easy target for SURF descriptors. The bottom box contains the project logo, which is a unique identifier.

These two images make for a unique and highly recognizable marker that can be easily tracked by the system under most affine transformations.

Feedback: Directions are conveyed to the runner in the form of tactile feedback. This is accomplished by a combination of three vibrotactors sewn into a small elastic belt (shown in Figure 6.11). These are used to tell the runner to slow down, speed up, move left or move right.

The team built a lightweight, portable, comfortable prototype. The system is able to follow a marker on a navigator's t-shirt, and relay directional corrections to the runner. The system, however, has a low frame-rate, making it appropriate for a walk rather than a jog or run. A future team will address the performance issues with the system.

The cost to produce the prototype was $374 in materials.

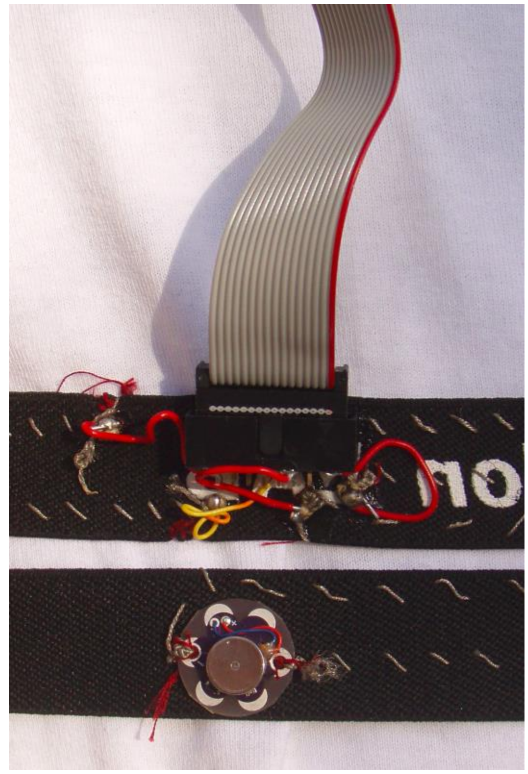

Fig. 6.11. Prototype of the tactile feedback actuator belt.

WII-B-FIT

Designers: Dominic Bertolino, Justin Gardner, Justin Kikuchi, Fanley Tsang
Supervising Professor: Dr. Lynne A. Slivovsky
Computer Engineering
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INTRODUCTION

The goal of the Wii-B-Fit project is to provide people with high-level quadriplegia opportunities for physical activity through an adapted video game experience. The underlying intent of the project is to provide an enjoyable gaming experience and a social one (i.e., one that can be experienced with other players). The system provides multiple health benefits by combining the social aspects of video gaming with the physical exercise involved. People with disabilities have less access to both of these benefits than those without. The current system is being designed for a local community member who was paralyzed in a car accident in 1982. He is a graduate of Cal Poly San Luis Obispo where he studied Social Science. He is also keenly interested in playing football and action games with the Wii-B-Fit.

SUMMARY OF IMPACT

Several customer requirements were identified as keys to a successful design. These included:

- The ability to control a minimum of two video games
- Easy and intuitive to learn and use
- Ergonomic by the client's standards.
- Lightweight so as to not limit a user's playtime
- Safe and durable

By satisfying these customer requirements, the team was able to design and develop a working prototype.

TECHNICAL DESCRIPTION

The team designed the system to incorporate a mouth-based game controller since their client has neck mobility. The overall system diagram is shown in Figure 6.13. The microcontroller receives input from the switches and sensors, interprets their data, and outputs converted signals to a standard Wii remote (Wiimote), which then communicates with

Fig. 6.12. Wii-B-Fit mouth-based game controller.

the Wii gaming system. One main component of the system is the gyroscope and accelerometer sensor combo. Together they sense the user's head movements that get mapped to the Wiimote direction pad. A mouth guard contains pressure-sensitive buttons that the user can actuate with his/her tongue. The pressure-sensitive buttons replace (with respect to functionality) the directional pad buttons on a standard Wiimote.

The Wii-B-Fit design minimizes the number of wires that are attached to the user. Since it uses features much like the classic controller, it works for more than one game. Using the directional pad as well as the three buttons, the user can play a wide assortment of games.

The design team created a proof-of-concept prototype and demonstrated the viability of the mouth guard-based controller. However, the physical prototype (i.e., the mouth guard) needs to be refined by a team with expertise in mechanical design. The cost to produce the prototype was $658 in materials.

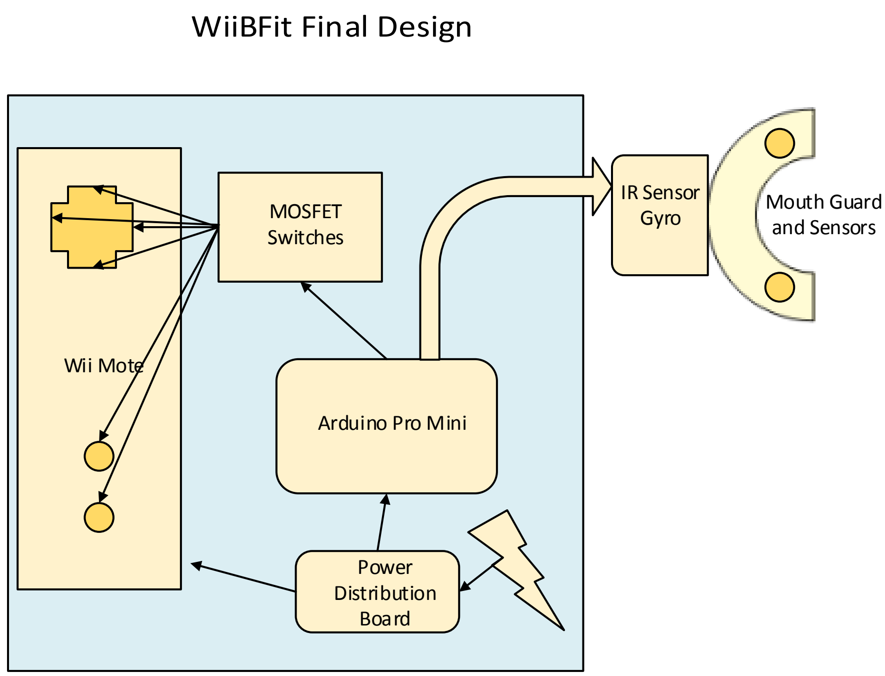

Fig. 6.13. Wii-B-Fit system diagram.

SIT SKI

Designers: Jonathan Gorski, Matthew Bissonnette, Kevin Izumiya,
Client Coordinator: Maggie Palchak, Disabled Sports Eastern Sierra
Supervising Professor: Dr. Joe Mello
Mechanical Engineering Department
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INTRODUCTION

The purpose of this project is to build a sit ski that is lightweight and adjustable for people with paraplegia. The customer is Maggie Palchak, who is the Paralympics Sport Program Coordinator at Disabled Sport Eastern Sierra. The main goal of the project was to provide a lightweight sit ski with the target weight of 10-11 lbs. so that a user can easily ski up and down different terrain. Our other goal was to increase adjustability of the sit ski so that it is adaptable for different ranges of disabilities (e.g., riders with lower spinal cord injuries prefer a lower seat back because it allows greater range of motion in the upper body). Riders with high spinal cord injury prefer higher seat back with a bucket seat for stability. Each rider will be able to choose an appropriate rider position by adjusting the leg rest, foot rest, and appropriate seat.

SUMMARY OF IMPACT

Eastern Sierra Disabled Sports is currently testing the ski. The leg rest was not thick enough, and vibrates during skiing. The changeable seat designs work well, and it possible that the clients can still use the sit ski with the feet tucked back under the device without the leg rest.

TECHNICAL DESCRIPTION:

Design Requirements:

- Building a lightweight frame
- Have two interchangeable seats; bench and bucket
- Adjustable leg rest
- Include lap, chest, leg, feet belt
- Rider must be able to brake and right oneself after a fall
- Provide two leg rest positions: tucked underneath the seat or strapped forward to the leg rest.

The final design consisted of two seats: a bench seat made of boat canvas material (Fig 6.14a) and a bucket seat made of molded plastic with foam padding (Fig 6.14b). Both designs were durable, water-resistant, and comfortable for the users to sit on for a long period of time. Each seat was attached to the mounting plate, which was welded to the seat frame. The frame was built from aluminum because it was lightweight, durable, and rigid. The ski had two Rossignol NNN bindings to attach the skis to the sit ski frame. Two inch straps are used to secure the chest, hip, and thigh, while 1" straps are used for the feet on the leg rest, resulting in four straps to provide stability. Straps are attached to the seat using 1" and 2" footman loops which are bolted directly to the seat. The leg rest is attached to the frame by 4 quick release pins. It is completely removable if the user wants to tuck their legs underneath the seat. The sliding foot rest on the leg rest is attached by 4 clamps that can slide up and down along the leg rest to accommodate different foot positions.

A detailed analysis was performed on the entire sit ski. Hand calculations were performed to provide an estimate sizing of the frame since the structure is statistically indeterminate. Multiple tests were performed to measure the strength, security, durability, and deflection in response to weight.

Total cost for the prototype was $960.

Spec	Parameter Description	Requirement or Target
1	Weight of Sit Ski	11 lbs.
2	Weight of Bucket Seat	4.8 lbs.
3	Weight of Bench Seat	4.7 lbs.
4	Weight of Frame	3.68 lbs.
5	Weight of Leg rest	2.68 lbs.
6	Heaviest rider	300 lbs.
7	Weight on leg rest	60 lbs.
8	Weight of clamps (8)	(0.25lbs x 8) 2 lbs.
9	Weight of straps	1 lb.
10	Height of bottom of seat	15.75 in (40 cm)

Fig. 6.14. Sit ski in two configurations – (a) bench seat and (b) bucket seat.

SECOND GENERATION POLYSTACK PROSTHETIC FOOT

Designers: Shalan Ertis, John Kearns, and Seija Maniskas
Client Coordinator: Matt Robinson, Hanger Prosthetics & Orthotics
Supervising Professor: Mohammad Noori
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INTRODUCTION

The Vida Nueva prosthetic clinic in Choluteca, Honduras, services patients who have lost limbs as a result of war, natural disasters, poor health, diabetes, and accidents. According to Program Director Reina Estrada, Vida Nueva is the sole service provider for the entire southern region of Honduras. Land mine accidents are rare, though they continue to be discovered sporadically. More typical for Vida Nueva are patients who have lost a limb from an accident incurred while attempting to jump aboard a moving train. This clinic, whose patients need durable and effective prostheses to be able to remain employed and support their families, would benefit greatly from the implementation of a low-cost foot prosthesis which can be manufactured on-site within a matter of hours. Because aesthetics are culturally important to the clinic's patients, this prosthesis should also fit within a locally available cosmetic shell with the appearance of a human foot.

SUMMARY OF IMPACT

The First Generation PolyStack foot was tested at the Vida Nueva Clinic, and met with positive reviews. Unfortunately, due to current conditions in Honduras, the team was unable to travel to the clinic to test the second generation foot. We are actively seeking other partners in Central America to test out the new version.

Improvements to the first generation include: (1) a block of vulcanized rubber below the ankle adapter which softens the heel and creates a smoother transition from heel strike to stance during gait, (2) additional and thicker intermediate layers which raise the ankle adapter to the top of the cosmetic shell and allow the heel to deform more upon contact with the ground, eliminating the need for a longer pylon, (3) altered layer profiles which fit the interior cavity of the Otto Bock Trias cosmetic shell, and (4) - A tailored heel shape in the lower layer of Delrin which fits snugly and securely into a heel pocket in the shell, locking the prosthesis into the shell for superior performance.

TECHNICAL DESCRIPTION:

Design Specifications:

- Fits snugly and securely inside cosmetic covers
- Made of Delrin plastic (aka: polyoxymethylene)
- Parts easily made with only a jig saw, drill press, grinder, and basic hand-held tools
- Foot design lasts for 3 years, by analysis
- Works with the prosthetic leg components currently used by Vida Nueva, ICRC and modular adapter.
- Materials cost less than $30
- Manufacturing time less than 3 hours

The primary material used in the Poly Stack foot is Delrin®, which is a self-lubricating thermoplastic made by DuPont™. It is durable and strong, but flexible enough to deform under the loads experienced by the Poly Stack Foot. Delrin® is relatively inexpensive and is available to the Vida Nueva clinic in Honduras. The secondary material is Vulcrepe. This is a vulcanized rubber material often found in the midsoles of shoes. It is durable, relatively compressible, and cheap. The Delrin® provides the structure and support for the Poly Stack Foot, and the Vulcrepe provides a cushion for the heel-strike phase of gait. The rest of the components consist of the fasteners used to hold the foot together. Four #6 X 2" bolts connect the Delrin® layers anterior to the ankle adapter. The Vulcrepe block is held in place by two slotted pins that pass through the rubber vertically and into the plastic above and below. Finally, an M10 socket-head bolt is used to attach the foot to a standard pyramid ankle adapter. This interface with the adapter is common among foot prostheses, and makes our foot compatible with most prosthetic legs in the world.

It is estimated that the second generation foot with cost $15.68 in materials, 2.5 hours of labor (at approximately $15/hr.), for a total cost of $53.18. Approximately $300 was spent on materials, test fixturing, and parts for the design project.

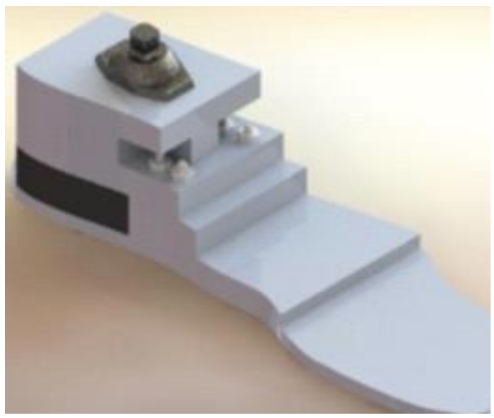

Fig. 6.15. Solid model of PolyStack Foot.

STRIDER II

Designers: George Cummings, Brian Kreidle, Ricky Lee, Clark Steen
Client Coordinator: Amy Stilts (mother)
Supervising Professor: Sarah Harding
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INTRODUCTION

The primary goal of the Strider project was to improve the life of a five-year-old boy, Nathan Cooper, and his parents, Amy and Bob. Nathan was born with Spinal Muscular Atrophy, or SMA, a condition that results in degenerated motor neurons in the spinal cord. SMA causes Nathan's muscles to atrophy and grow extremely weak to the point that he cannot support his own body weight while standing. As a result, Nathan spends much of his life sitting or lying down, which may eventually cause other health problems such as low bone density and poor circulation.

A standing rider, or Strider, will give Nathan the opportunity to spend more time standing up and moving his body. Standing up more often will engage many of his muscle groups and in turn, possibly improve his health. Also, a standing rider will allow Nathan to interact with the world around him with fewer restrictions that result from SMA. This can greatly increase Nathan's quality of life as well as that of his parents.

SUMMARY OF IMPACT

After testing ascertained that the product was safe, Nathan tried it out to see what he and his parents liked and disliked about it. The team monitored his ability to walk while supported and gauged how much he enjoyed it in comparison to his other assistive devices. There was a very positive reaction from Nathan and his parents. It seemed, in their opinion, to be superior in comfort and ease of use to Nathan's other devices. In order to develop a great final product, the team made some final modifications to guarantee the highest level of safety and the utmost satisfaction with the Coopers. The final iterations of the Strider included reinforcing the carbon fiber tubes and painting and labeling the frame according to Nathan's preference. After preliminary testing and a final showing at the Design Expo, where Nathan used his Strider for the second time, it was clear that this will be a very useful device for Nathan and his family. Currently, a kinesiology student is working with the family to develop a full set of exercises to help Nathan get maximum benefit from the Strider.

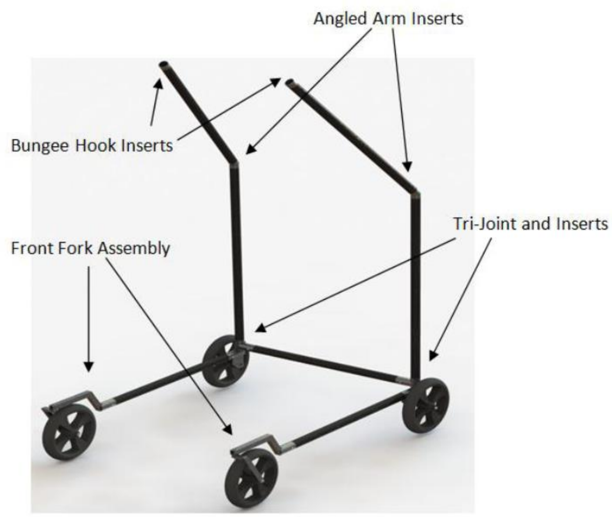

Fig. 6.16. Solid model of the Strider.

TECHNICAL DESCRIPTION

The student team developed an extensive list of design goals. The Strider should:

- Enable Nathan to ride comfortably in multiple standing positions, including one that permits him to swing his legs freely and another that allows him to rest. These are high risk qualities because they represent some of the primary functions of the Strider.
- Have the possibility of being motorized and powerful enough for mild off-road conditions. This is a medium risk because a final design could function with or without a motor.
- Have some form of shock absorbency to increase the ease of use and comfort for Nathan. This is a

medium risk accessory that would make the product more convenient for its user.

- Be adjustable to make the device usable for a wide range of body sizes and more convenient overall for primary and secondary users. This is a desirable, medium risk objective that is not necessary given the project's primary objective.
- Be a collapsible product for convenience of transportation and storage. This will make the product more appealing, but is not an essential quality, so is a medium risk.
- Include a drink holder or food tray. This is a low risk addition because it is not required to meet the main goals of the project.
- Be compatible with Nathan's Hip Knee Ankle Foot Orthosis (HKAFO), which is an orthopedic device that supports Nathan's legs. This objective is desirable but not essential given Nathan's desire to swing his legs, so it is a medium risk. Depending on the design and based on the wishes of Nathan and his family, the device could function properly regardless of the inclusion of Nathan's braces.
- Be safe. The most critical and highest risk criteria for this device involve safety. The Strider must be stable and dependable for its intended use. It should be designed such that it will not fail under its intended or more extreme operating conditions. The health and safety of Nathan is the primary concern of this project, so this objective will receive the most attention.
- Be relatively lightweight. Weight is a high risk objective that will substantially affect the final design and its overall usefulness and safety. The total loaded weight and how it is distributed will be given a high level of attention in the Strider design.
- Be sized to accommodate aesthetics, safety, transportability, and functionality. In other words, the size of the final product is critical for fulfilling its primary functions. The size with respect to safety will be given the most attention, but there is some room for variation, so it is a medium risk.
- Have a reasonable cost of manufacturing. The cost of the Strider will affect the accessibility of replication by other families. This is not an extremely limiting requirement and can be adjusted slightly if needed, so it is a medium risk.

With these considerations in mind, the team chose carbon fiber (see Figure 6.16) with aluminum joints for the Strider frame. A carbon fiber frame can withstand repeated impacts and bending loads, and is light enough to be carried with one arm. Aluminum provides the necessary strength at critical locations. The frame has attachment points for the wheels and suspension system. The wheels and bungees are attached to the frame with carabineers that hook to aluminum inserts.

Finally, in order to make the frame collapsible, the four base joints and the wheels are attached with quick-release connections. This was accomplished using pins that fit through holes machined in the aluminum tubes. Carbon fiber components were adhered to the joints with epoxy and were tested to guarantee an acceptable bond was created between the two materials. The final frame is strong, lightweight, and has detachable parts for ease of use. The front wheels are a durable foam material and are connected to a swivel fixture which can be attached via the quick-release mechanism to the frame.

The harness is the only subsystem that directly interfaces with Nathan by holding him in a standing position. It is therefore is a key component of the overall design. Nathan's comfort is a top priority because if this device makes him feel uncomfortable after only a few minutes, he will not want to use it. The harness distributes his weight so that he is not supported just between his legs like many of his current harness systems do. The harness supports Nathan's upper body as well since his core muscles are not strong enough to stabilize his torso in a standing position. The harness used for Strider is called the Kaye Suspension Harness. It is ideal for supporting Nathan in the critical points and appears to be very comfortable. This harness is versatile because it can be used on other devices that suspend Nathan.

Finally, bungee cords, or extension springs, are attached to Nathan's harness and to the overhanging tubes with carabineers. Many variations of these extension springs could be used, but the current design uses adjustable bungee cords with simple hooks. The extension springs help support Nathan's weight and allow him to walk, bounce, and stand with his weight supported. These extension springs can be purchased in a variety of lengths, stiffness's, and load capacities.

Nathan wanted his Strider to be blue. The painting process consisted of masking the insert areas so that they do not get painted and ruin the clearance fit, spraying on a primer, and finally spraying on two coats of the final blue color.

Extensive testing on the frame was performed to ensure the structural stability of the device (see Figure 6.17). The Strider must not only work in conjunction with Nathan, but also assist him without additional hindrances. This is why the team spent a lot of effort and time defining what they called the "Nathan Factor." The "Nathan Factor" is a combination of typical human factors, such as ergonomics, and Nathan's enjoyment in using the Strider. These factors are extremely important and cannot be overlooked. The old Strider was well designed for strength and safety, but it was unable to properly cater to Nathan's other needs. As a result, it had a very high safety factor, but Nathan was unable to use or enjoy it. With the new Strider, we made sure to avoid the mistakes of the previous Strider by dealing carefully with Nathan's ability to enjoy using the final product.

Thus, properly designing and testing of test pieces was critical. Safety is the highest concern and an appropriate safety factor was chosen. Since we needed to make the Strider as light as possible, the amount of stress and loading on the frame and the suspension was carefully designed and tested. We tested different carbon fiber layups with the same epoxy and aluminum tube sizes in our final design in order to create the lightest and safest frame structure possible within our budget.

As mentioned earlier, Nathan's comfort is also very important. Even if the Strider does everything else perfectly, Nathan will not want to use it if it causes him discomfort. This is one of the main reasons why Nathan does not use his KidWalk—it is extremely uncomfortable and he cannot spend much time in it. Hence, the design of the harness, how the extension springs suspend him, and the connecting points on the harness and the frame are very significant. The connecting points must be placed so that he feels most natural in the upright position; the Strider should not constantly pull him into a position that is unnatural and uncomfortable. One of our biggest concerns with the Strider lies with the harness design. The harness is the only component that physically connects Nathan to the Strider. This component is where we expect comfort to play the most critical role. With the help of our kinesiology partners, we researched many potential harness designs and tested the Kaye Suspension Harness used in our final design with Nathan. We suspended him in the harness from a rig and observed him to determine his level of comfort and the most effective locations for bungee cord connection points.

The total cost of the Strider was $1250.

Fig. 6.17. Testing the frame.

Fig. 6.18. Nathan in the Strider.

CHAPTER 7
DUKE UNIVERSITY

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Principal Investigator:

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SWITCH-CONTROLLED BALL SHOOTER

Designers: Laamia Islam, Anurag Kondapalli, Lydia Lim, Prithviraj Singha Roy
Client Coordinator: Roger Schultz
Supervising Professor: Larry Bohs
Department of Biomedical Engineering
Duke University
Durham, NC 27708

INTRODUCTION

Students with disabilities in Mr. Schultz's classroom at Riverside High School enjoy physical, interactive activities. The goal of this project is to create a safe and fun device that launches balls at the press of a switch. The Switch-Controlled Ball Shooter (SCBS) is based on a modified ball pitcher. Two modes allow balls to shoot either repeatedly after a short delay, or upon each press of a light-touch switch. The shooter rests on a rotating base for aiming the shot. LED's on the base provide a visual indication that a shot will soon occur. With this device, students can enjoy physical interaction by shooting balls at each other or their teacher.

SUMMARY OF IMPACT

The Switch-Controlled Ball Shooter enables students with disabilities to participate in a stimulating activity.

Previously, Mr. Schultz found that students enjoyed the surprise and excitement of having balls thrown at them. With the device, students can "throw" balls themselves, making the activity much more engaging and empowering. Because the SCBS can be activated by any commercial switch, students with a wide range of disabilities can participate. Mr. Schultz commented, "The shooter has been a lot of fun and enabled my students to engage in playful and enjoyable interactions with the people around them. The shooter project enables them to engage in fun interactions previously beyond their physical abilities."

TECHNICAL DESCRIPTION

The Switch-Controlled Ball Shooter (Figure 7.1) comprises a Lazy Susan base with acrylic cover and LED's, a ball shooter, a helical ramp, a control box, and a touch-pad switch. The base is a 19" diameter, wooden Lazy Susan with 360 degree rotation, allowing shots to be aimed as desired. A blue circular piece of ¼" acrylic mounts to the top of the base, and contains 36 embedded LEDs that sequentially light up before the ball is launched.

Fig. 7.1. Switch-Controlled Ball Shooter.

A modified MLB pitching machine (Franklin Sports model 6696S3) attaches to the base. This machine contains two rotating wheels, each powered by a DC motor, which shoot balls as they pass between the wheels. A custom yellow exit tube, 4.75" in diameter and made using a 3D prototyping printer, attaches to the mouth of the pitcher to prevent hands from reaching the rotating wheels. A detachable helical ramp, supplied with the pitching machine, allows several balls to be loaded for successive shooting.

The 7x5.6x2.5″ control box is made of ¼″ acrylic and contains custom circuitry and six D batteries. One side of the controls box is slanted, providing a platform for a commercial 4.5x6″ light-touch switch (Pal Pad). The switch cord plugs into a 1/8″ jack on the side of the control box, allowing the SCBS to be activated with any commercial switch.

The device can operate in either switch or automatic mode. In switch mode, a press of the switch activates a microcontroller (PICAXE-X22), which triggers a ball to shoot after a ten second delay During this time, 36 LED's, mounted on the acrylic base, light sequentially to help the student to anticipate the shot. In automatic mode, balls launch every ten seconds as long as the device senses a loaded ball via a weight-activated switch. A speed control knob on the side of the control box varies the voltage to a regulator circuit, which allows the user to select the desired velocity, thereby providing a shot range of 6-16′.

Figure 7.2 shows a student operating the device. Replacement cost is about $185.

Fig. 7.2. Student using Switch-Controlled Ball Shooter.

THE EASY REACH BOOKBAG

Designers: Auriel August, Ophelia Chua, Jesse Liu, Kartik Pawar
Supervising Professor: Larry Bohs
Department of Biomedical Engineering
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INTRODUCTION

Our client, a 13-year-old student with TAR syndrome, typically requires assistance carrying his books, laptop, and other supplies around school. The Easy Reach Bookbag is pulled behind the user and stands independently at a height that is comfortably accessible. The bag is easily removed, and the device fully collapses, making it easy to transport. The Easy Reach Bookbag allows the client to move his school supplies independently, and to store and retrieve supplies comfortably and without external assistance.

SUMMARY OF IMPACT

The Easy Reach Bookbag allows our client to perform daily school tasks independently. School materials are raised to the ideal height for the client while seated at a desk. Because the device collapses to 2′x2′x1′, it is easy to transport and store. The client commented: "a perfect height for my desk and it fits my laptops and book just the way I wanted."

TECHNICAL DESCRIPTION

The Easy Reach Bookbag (Figure 7.3) includes a modified messenger bag (Timbuk2) and a modified handtruck frame (Magna Cart).

Modifications to the messenger bag include an internal structure, an internal item platform and a folder divider. The 9″ x 16″ x 4″internal structure holds the bag open and is made from two heat-bent HDPE (high-density polyethylene) pieces attached by L-brackets. The HDPE item platform (9″-8.75″ x 3.75″ x 0.25″) is braced against the internal frame by a triangle bracket and connected by Velcro for easy removal. The commercial folder divider (11.5″ x 12.75″ x 3.63″) allows easy organization of supplies. The messenger bag is held closed and open using Velcro, which is easy for the client to operate.

Fig. 7.3. The Easy Reach Bookbag.

Modifications to the handtruck frame include a base support and handlebar extensions, two U-shaped aluminum brackets and a caster wheel (2″ diameter) on the base. The caster wheel has a locking mechanism to prevent rolling when the user desires.

The base support comprises an attachment to the handtruck (4″ x 5.5″), a horizontal flap for the bag (12″ x 8″ x 0.5″), a front flap (12″ x 9.25″ x 10.25″ x 0.5″) and an L-bracket (2″ x 2″ x 0.25″), all made from black HDPE. The horizontal flap supports the messenger bag. An L-bracket on the front of the horizontal flap helps hold the bag in place. The front flap has an arch cut-out of 3″ in diameter, with the apex of the arch measuring 5.5″. The ends of the front flap arch are beveled to rest securely within two aluminum U-brackets (2.5″x 0.75″ x 0.75″) mounted on the base of the handtruck frame, holding the horizontal shelf upright. Hinges attach the horizontal flap to the frame, and the front flap to the horizontal flap, allowing the device to easily collapse.

The handlebar extensions comprise two friction hinges, two stopper pieces (1.5″ x 1.75″ x 0.5″), two height adjustment pieces (8″ x 1.75″ x 0.25″), two extension pieces (15″ x 1.75″ x 0.25″) and a backing piece for the backpack straps (10.5″ x 6.5″ x 0.25″ with a 1.5″ perpendicular bend at the top), all made from HDPE. The backpack straps can be repositioned to accommodate the client's growth by repositioning the extension and height adjustment pieces using two screws. The entire mechanism retracts and folds, using the friction hinges and spring loaded height-adjustment mechanism of the handtruck, for storage and transport. Padding on the top bend of the backing piece aids client comfort.

Figure 7.4 shows the client making a right turn in the school hallway. The replacement cost of the device is about $315.

Fig. 7.4. Client walking in the school hallway with the Easy Reach Bookbag.

THE BOPPER

Designers: Amogh Karnik, Dyuti Mahendru, Brittany Potter, Roshan Sadanani
Client Coordinator: Roger Schultz
Supervising Professor: Larry Bohs
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INTRODUCTION

Students in Mr. Schultz's classroom at Riverside High School have limited opportunities to interact due to physical and cognitive disabilities. Mr. Schultz has found that many of the students enjoy being playfully "bopped" with a foam noodle. However, the students cannot bop Mr. Schultz or each other. The goal of this project was to develop a device that allows the students to bop one another independently. The Bopper includes a control switch and an electromechanical mechanism contained in a rotating housing. When the switch is pressed, the mechanism quickly drops a foam noodle and then returns it to its vertical starting position. The Bopper is fun, easy to use, and allows students to enjoy an interactive activity.

SUMMARY OF IMPACT

Previously, students relied on teachers, therapists, or peer helpers to engage in any type of physical interaction in the classroom. The Bopper allows students to independently engage with their fellow students, in addition to their teachers and peer helpers. Mr. Schultz commented, "Before the Bopper became available to them, [my students] could participate only in a passive way, and now the Bopper project has empowered them to engage in fun interactions previously beyond their physical abilities. This project has brought a lot of fun and lively interactions to my class."

TECHNICAL DESCRIPTION

The Bopper is comprised of a rotating base, a motor mechanism, a noodle mechanism, control circuitry, a control switch and a custom housing.

The rotating base is created from two pieces of 0.25" HDPE (high density polyethylene) cut in an octagonal shape and attached to a commercial Lazy Susan. Handles on the top piece make the device easy to carry and to rotate to the desired direction.

Fig. 7.5. The Bopper.

A 20 RPM DC gear motor attaches to one side of the top base piece. An offset shaft, created by attaching a 2.7x1x0.5" piece of aluminum to the motor shaft, rotates as the motor turns. A drive pin mounted parallel to the motor shaft thereby provides an offset shaft to move the noodle mechanism.

The noodle mechanism consists of an aluminum shaft, spring, and hinge. The shaft attaches to the base using the hinge, while the spring connects between the shaft and the base. The aluminum shaft has a cross section of 0.5x1″ so that the axial hole of a standard foam noodle fits snugly. An L-shaped section at the bottom of the shaft provides a lifting surface for the motor drive pin. The noodle mechanism is mounted such that as the motor rotates the drive pin, the noodle mechanism lifts until the pin clears the L-shaped section, thereby allowing the shaft to drop quickly, pulled by the force of the extended spring.

A commercial pushbutton switch is mounted in a custom housing made from PVC pipe, foam, and velvet. Pushing this "bop" switch activates a control circuit, which is powered by eight AA batteries. The circuit rotates the motor until a normally-closed switch senses that the Bopper shaft is vertical. The system then rests until the user pushes the bop switch, which starts the motor rotating, disengages vertical-sense switch, initiates a bop and returns the bopper noodle to vertical.

A custom housing contains the bopper mechanism, circuitry and batteries. A 1/8″ jack on the housing accepts the plug of the bop switch. Any commercial switch with a 1/8″ plug can be used, allowing accommodation for students with a wide range of disabilities. The housing is covered with purple velvet, the school color.

Figure 7.6 shows a student using the bopper. The cost of the components for the device is approximately $240.

Fig. 7.6. Student using the Bopper with his teacher, Mr. Schultz.

THERAPEUTIC PEDAL CAR

Designers: Amanda DeQuattro, Jamie Leong, David Houck, and Izundu Obi-onuoha
Client Coordinator: Dr. Melissa Scales
Supervising Professor: Larry Bohs
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INTRODUCTION

Our client is a four year old child with cerebral palsy who enjoys playing in a Little Tikes push car. However, because of the unequal strength in extending compared to flexing his legs; he typically pushes himself backwards, eventually running into a wall or other obstacle. The goal of this project is to create a car that moves forward while the client extends his legs. Additional goals are to provide a steering mechanism the client can operate, and to improve the client's interaction with other children on the playground. The Therapeutic Pedal Car uses a modified Power Wheels toy car with custom left/right pedals, a control circuit, and a steering extension bar. Using the device, the client can use his legs to move forward, thereby improving his independence and fostering interaction with other children on the playground.

SUMMARY OF IMPACT

With the modified Power Wheels car, the client can drive forward and utilize his vision and modified steering wheel to avoid obstacles. Other children have been excited to see the client using the car, thereby increasing his contact and interactions. The client's therapist commented, "The biggest benefit of the car built for (the client) is that other children in his class now flock to him and play with him and the car when before he was a solo kiddo when he played."

TECHNICAL DESCRIPTION

The Therapeutic Pedal Car (Figure 7.7) comprises a commercial Lil Ford Power Wheels car, two switch pedals, a control circuit, an extended steering bar, a seat belt, and an emergency stop switch. Two commercial foot switch pedals (Hosense HF1) attach to a wooden panel, which is secured to the foot area of the powered car. The pedals are oriented with the compressible side upward to provide easiest actuation by the client. If desired, the force required to push the pedals can be varied by the client's therapist by removing the top piece of each pedal and

Fig. 7.7. Therapeutic Pedal Car .

changing to stronger springs, which have been provided. To help keep the client's feet in proper position for the pedals, a curved piece of high-density polyethylene is secured between the car seat and pedals, two wooden panels are attached to the outer side of each of the pedals, and an upright foam noodle is placed between the pedals. Additional foam noodles rest on either side of the seat, keeping the client centered and secure.

The control circuit includes a PICAXE microcontroller, programmed using BASIC code. The circuit senses when a pedal is pressed, then drives the car's motors for three seconds. If the opposite pedal is pressed within that time, the car continues to move; otherwise, the car stops. This algorithm requires the client to use alternate kicking motions to drive the car continuously. An amplifier based on a Darlington power transistor transfers the drive signal from the control circuit to the car's motors. The circuit is powered by the commercial car's 12V battery, regulated to 5V for the microprocessor.

Because the client is not strong enough to turn the car using the commercial steering wheel, an extended steering bar, made from three pieces of 1" PVC pipe and two 120 degree connectors, attaches to the wheel. Rubber grips on the ends provide comfort and grip for the client.

A continuous seatbelt (McMaster) secures the client in place while driving. The length is adjustable to allow for the client's growth and use by other children. An emergency stop switch disconnects the circuit from the Power Wheels motor. This switch is mounted to the rear of the car, so that a teacher or therapist can quickly stop the car by pushing the switch if necessary.

Figure 7.8 shows the client driving the Therapeutic Pedal Car. Cost of components for the device is $275.

Fig. 7.8. Client driving the Therapeutic Pedal Car.

KITCHEN KADDY

Designers: Taylor Jordan, Sarah Omenitsch, Catherine Ramsey, Margaret Upshur
Client Coordinator: Susan Salzberg
Supervising Professor: Larry Bohs
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INTRODUCTION

Everyday kitchen tasks are often difficult for our client due to limited fine motor skills caused by Charcot Marie Tooth disease. The Kitchen Kaddy allows the client to transport kitchen items more efficiently and provides support and stability to prevent fatigue as she performs these tasks. The project uses a modified commercial walker, consisting of three closed sides and one open side. The design includes a large front tray and a removable side basket that facilitate transport of kitchen items. Finally, the walker incorporates a braking system that defaults to the locked position to give the client stability when she stops. Ultimately, the Kitchen Kaddy increases the client's independence, efficiency, and comfort in performing routine kitchen tasks.

SUMMARY OF IMPACT

The Kitchen Kaddy gives the client a sense of independence in the kitchen that she has not seen in recent years. Using the Kaddy, she is more efficient and confident. The client commented, "(the) Kitchen Kaddy offers safety for me from falling when performing kitchen tasks. My dishes will last longer because they will travel on the tray rather than fall from my hands. When I transfer knives I will not be at risk of falling on the knife. I can now move 6 plates at a time, not just one."

TECHNICAL DESCRIPTION

The Kitchen Kaddy (Figure 7.9) includes four main components: a walker frame, front tray, braking system and side basket.

A commercially available bariatric walker (ConvaQuip) provides the framework for the device. This walker is heavier and stronger than a standard model, with a maximum load of 750lbs. The geometry and weight of the walker make it difficult to tip, while the high load limit ensures the device can withstand the load from the user and the items in the tray and basket. The walker handgrips are adjusted to a comfortable height for the user (30"). To minimize the tendency to tip created by the front tray, the rear legs are cut shorter than the front legs by 1.25", and steel rods are inserted into the rear legs to shift the center of mass lower and toward the rear. The wheels of the commercial walker are removed because they make the walker move too fast for the client. After testing several alternatives, felt pads were attached to the leg tips to provide the best balance between maneuverability and stability.

Fig. 7.9. Kitchen Kaddy.

The 18" by 13" front tray is made from ½" black high-density polyethylene (HDPE), attached to the walker frame with two 10" L-brackets. Testing revealed a maximum capacity of 70 lbs., providing a safety factor of 3.5 compared to the expected maximum load of 20 lbs. Three sides of the tray attach to the base with piano hinges, allowing them to hinge downward, locking in the vertical position with cabinet roller latches. A Dycem mat covers the tray, creating a non-slip surface to hold objects steady while the walker is in motion.

The braking system incorporates two custom legs, constructed from bent steel pipe and attached to the front of the walker frame. Two conduit clamps allow the legs to slide vertically when actuated by bicycle cables and locking hand levers (Mimi Lite Allegro Medical, Deluxe Aluminum Rollator Accessories #127B-AE3EC93).

Reducible-force gas springs (McMaster) exert a downward force on the braking legs when the levers are in the lower position, causing rubber feet on the leg tips to contact the ground, making the walker much more difficult to slide. Moving the levers upward lifts the braking legs off the ground, allowing the walker to slide easily on the floor.

A commercial wire-mesh basket attaches to hooks on a stationary piece of HDPE, secured between two aluminum supports on the side of the walker frame. Figure 7.10 shows the client using the Kitchen Kaddy. Cost of components for the device is approximately $600.

Fig. 7.10. Client using the Kitchen Kaddy.

KAYAK TRANSPORTER

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INTRODUCTION

Our client is a competitive kayaker with spina bifida. She desires to independently transport her kayak from the car to the dock so that she can train for the Paralympics. The Kayak Transporter consists of a modified wheelchair, a front attachment, a rear attachment, and a combing lasso. The kayak is placed on the rear attachment and slips into the front attachment. The front attachment connects to the modified wheelchair using a rotating hitch, allowing the client to tow the kayak behind her. A tow rope and reel allow the kayak to be pulled up steep slopes without being attached to the wheelchair. Using the Kayak Transporter, the client can transport her kayak from her car to the water and back independently.

SUMMARY OF IMPACT

Our client is an avid kayaker training for the US Paralympics team. While she has an accessible car rack for her kayak, she previously required assistance at the lake to move the kayak to the water and back. The kayak transporter allows her to do these operations by herself, making it far easier to schedule consistent workouts. She commented, "I am so pleased with the end product! I am inspired to keep parakayaking in spite of all the challenges that my body seems to give me. Being able to get on the water before the sun comes over the tree line will be huge for training."

TECHNICAL DESCRIPTION

The kayak transporter consists of four components: a modified wheelchair, a front attachment, a rear attachment, and a combing lasso.

The modified wheelchair is equipped with two 25′x2′′ knobby tires, allowing far better traction on loose, muddy and uneven terrain compared to the original street tires. Two 6″ pneumatic front casters provide similar advantages over the original narrow casters. A custom hitch includes a clamp and pin. The clamp is made from a block of aluminum, drilled to accommodate the rear handle of the wheelchair and then cut in half. Four ¼-20 bolts secure the clamp to the handle. The pin is a ½′′ threaded steel bolt that screws into the bracket, beveled to a round tip to facilitate attachment of the hitch arm, described below.

Fig. 7.11. Kayak Transporter.

The front attachment interfaces with the modified wheelchair via a hitch arm, a 12′′ long x 1′′ square aluminum rod with a 0.6′′ diameter hole for the hitch pin. The frame of the front attachment is constructed using 1′′ square aluminum rods. A nose sheath integral with the frame is comprised of two ¾′′ diameter, custom-bent aluminum pipes. Both the front attachment frame and the nose sheath are padded using foam insulation to prevent damage to the fragile kayak body. A 5′′ platform caster wheel bolts onto the bottom of the front attachment frame. This wheel raises off the ground when the front attachment hitches to the wheelchair, but allows mobility of the kayak when not attached to the wheelchair.

The rear attachment is composed of a rear cradle, a rear attachment frame and wheels. The rear cradle is made from two separate ¾′′ diameter pieces of custom-bent aluminum pipe. The frame is constructed using 1′′ square aluminum rods. A 1/16′′ thick, ¾′′ wide L-bracket cross-bolts onto the rear attachment frame and is combined with a rubber end cap to form a brake stand. This stand holds the rear attachment steady while the kayak rear is loaded. The rear attachment wheels comprise 26′′ knobby mountain bike tires on aluminum frames. The wheel hub axles are modified using sealed ball bearings, press fit into custom bronze sleeve, allowing them to interface with holes in the rear attachment using ½" quick-release pins. This allows the client to quickly and easily attach and detach the rear wheels from the rear attachment for storage in her car.

The combing lasso, composed of ½'' nylon straps and corresponding buckles, secures the front attachment, the kayak, and the rear attachment to each other. During testing, the client had difficulty pulling the transporter up the steep, muddy hill from the dock. A rope with buckle is provided to attach to either end of the transporter, so the client can pull the kayak up the hill after climbing the hill with her wheelchair only. A metal reel allows the rope to be stored without getting tangled.

Figure 7.12 shows the client using the Kayak Transporter. Replacement cost for the device is about $400.

Fig. 7.12. Client using the Kayak Transporter to move her kayak to the lake.

SEED PLANTING ASSISTIVE DEVICE ENTOURAGE (SPADE)

Designers: Jennifer Chien, Bill Lee, Linda Ye, David Yudovich
Client Coordinator: Gena Brown
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INTRODUCTION

Volunteers with disabilities at the Goodwill Industries of Eastern North Carolina (GIENC) Nature Center experience difficulties with hole spacing, hole digging, and delicate seeding functions. The goal is to implement solutions that will make their routines more accessible, while allowing them to be independent and maintain close interaction with the ground. The Seed Planting Assistive Device Entourage (SPADE) includes 1) a spacing device for hole alignment and positioning, 2) a digging device for fixed diameter and variable depth adjustment, and 3) a seeding device for output of 1-3 small seeds. Ultimately, this system helps volunteers perform tasks with higher accuracy, gain independence, and develop a sense of accomplishment.

SUMMARY OF IMPACT

SPADE helps alleviate an otherwise tedious and time-consuming planting task for all volunteers and staff at GIENC. The spacer marks the hole with even spacing and alignment for beds of various dimensions. Staff commented, “It’s a tool that lends itself well to flexibility”. The digger provides a more ergonomic and easier method to dig holes of consistent depths. Staff noted that “it will be beneficial to those with visual impairments and also those with special difficulties”. The seeder quickly and reliably dispenses small seeds directly to the planting hole, and can be operated by people with wide variety of disabilities. Staff commented, “We like the concept of the seeder. It worked with small and large hands alike and felt natural to use.”

TECHNICAL DESCRIPTION

The spacer comprises spacing rods, connecting rods, arrow markers, 4″ ring spacers, 4″ and 2″ ring ground markers, spacer quick release pins, connector anchor bolts, and spacer attachment bolts. The spacing rods are made from 4′ long, 1″ square aluminum tubing with 9/32′′ holes interspaced at 1′′ intervals. The outermost holes on each rod are 3/8″, accepting 8″ long anchor bolts that fix the spacer securely in the ground. The connecting rods are made from 1′ or 2′-long aluminum tubing with 1/4′′ connector holes. The connecting rods attach flexibly to the spacing rods via commercial L, I, and T nylon resin connectors, secured with ¼″ diameter quick release pins. The arrow markers, constructed from Z-shaped aluminum stock, fasten to the spacing rods at the desired intervals using ¼″ bolts and wing nuts, marking the location for future seeding holes. The 4′′ ring spacers, constructed from 4″ diameter PVC pipe cut into 1″ lengths, fasten to the spacing rods using aluminum L-brackets and ¼″ bolts. The 4′′ and 2″ diameter ring ground markers are 1″ tall PVC rings that are inserted into the ground to accommodate non-linear arrangements of desired holes.

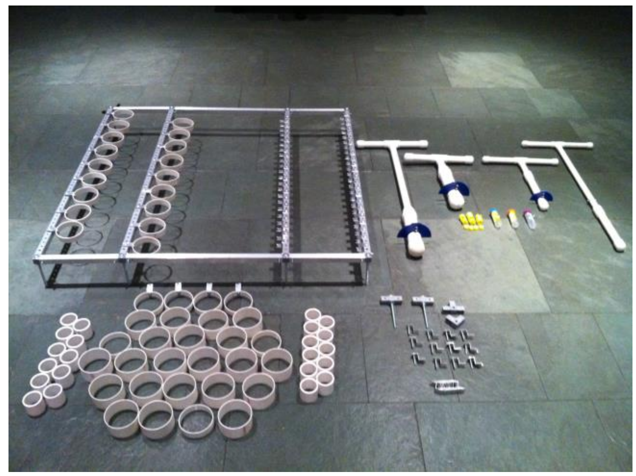

Fig. 7.13. Seed Planting Assistive Device Entourage.

The digger comprises an end-capped PVC tube and T-handle with adjustable depth indicator. Four diggers are provided to accommodate 1″ and 2″ holes in both raised and ground-level beds. The shorter diggers (raised beds) are 20″ long, while the longer ones (ground beds) are 40″ long. End caps on the bottoms of each digger prevent soil penetration. The depth indicators are made of 1/8′′ thick white HDPE plastic cut in the shape of a semi-circle, bolted to metal L-brackets and connected to the digger tubes using quick release pins. The diggers create consistent holes for planting in the soft soil typical at GIENC.

The seeder is comprised of a dispensing tube, cylinder, lever, torsion spring, and seeder disk. The dispensing tube is a commercial 50 mL polypropylene conical tube with a screw-cap. The cylinder, constructed from ABS plastic using a 3D prototyping printer, fits into the dispensing tube and is held in place by a holding bolt and lever. The cylinder consists of a loading channel where the seeds are placed, a seeder disk channel where different seeder disks are inserted, and a dispensing channel where the seeds dispense. A smaller spring channel parallel and to the right of the dispensing channel holds a 0.4″ diameter torsion spring in place. A 0.25″ lever channel cut into the side of the cylinder allows a lever (1/4″ screw eye) connected to the seeder disk to rotate 100°. The lever translates linear to rotational motion from the user's thumb or finger on the lever to the seeder disk. The torsion spring returns the seeder disk from the loading position to the neutral or dispensing position.

The seeder disk, also made with the 3D printer from ABS plastic, rotates within the cylinder, held in place by the torsion spring and a flat-head screw. A holding channel is 90° relative to the loading channel. Clockwise rotation of the disk aligns a holding channel within the disk with a corresponding loading hole in the top of the cylinder, loading a small number of seeds into the disk. Counterclockwise rotation of the disk dispenses the seeds. The cost of the components for all the devices is about $400.

Figure 7.14. Clients using the spacer and digger (left) and seeder (right).

READING RAINBOW

Designers: Shalki Kumar and Eason Lee
Client Coordinators: Laura Walton, teacher and Edie Kahn, OTR
Supervising Professors: Kevin Caves and Richard Goldberg
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INTRODUCTION

Our client, Mit, is a nine year old boy who has been diagnosed with a rare genetic disease, neurofibromatosis type 1. As a result, Mit has visual impairments, as well as fine and gross motor limitations. He also has difficulty in activities that require oculomotor coordination and precision, such as pointing at words, writing, sorting fine objects and arranging things in the correct order. This results in difficulties for reading and writing activities in school, as he has trouble tracking his location on the page and often gets distracted by pictures and other information. To address these issues, his teacher and therapists block off sections of the page to highlight the part where they want him to focus his attention.

There are commercially available reading focus cards that could help Mit with reading and writing. However, their view window is fixed and thus cannot be implemented for reading variable size text. We developed the Reading Rainbow, which provides a variable size view window to help Mit focus his attention on the page during reading and writing activities. This device is easy to use, durable, and portable. The device also has a place to keep Mit's sticker prize book and digital timer.

SUMMARY OF IMPACT

The Reading Rainbow device has tremendous potential to assist the client's learning capabilities. The device allows Laura (client's teacher) and Edie (client's occupational therapist) to "block off distractions on a page so that he can really focus on recognizing the words that he is working on being able to read and memorize." The window capabilities assist Mitt with his writing by "creating a small space in which he forms letters so he doesn't have the room to scribble all over the page." Both Laura and Edie feel that "with continued use, [the Reading Rainbow device] is really going to help him start to be able to track things visually better and to control his writing and his use of page space will be more controlled."

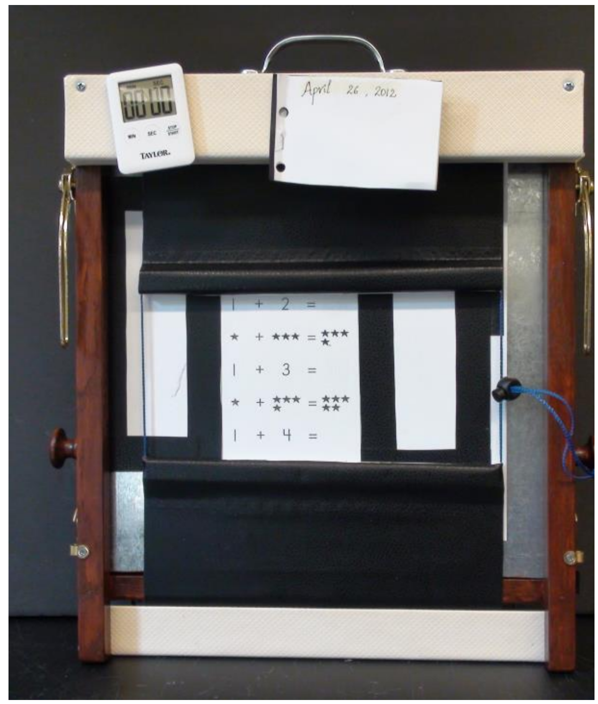

Fig. 7.15. The Reading Rainbow device. A pair of dark shades mask out the top and bottom portions of the page, and these shades can slide up and down to reveal different parts of the page. The height of this viewing window can be adjusted using the drawstring on the right. Also, magnetic sheets can be used to block the left and right sides of the page.

TECHNICAL DESCRIPTION

The device consists of a base and a frame, attached together with a hinge along the back edge. The user can lift the front edge of the frame, place the worksheet or book on the base, and close the frame over it. The user can adjust the viewing window in the vertical dimension by sliding a pair of roller shades. A drawstring adjuster allows for changes in the height of the viewing window. A digital timer and a badge book are attached to the device magnetically. The entire device is portable, and there is a carrying handle along the back edge.

The base of the device is a 14 X 14 inch plywood sheet, which acts as a platform for the book/worksheets used by the client. A metal sheet covers the top surface of the base so that it is magnetic. White magnetic sheets can be used to hold the book/worksheet in place. In addition, these magnetic sheets can be used to adjust the size of the opening in the horizontal direction as they can be dragged out or slid inside.

The oak frame rests on top of the base, and it is hinged along the back edge so that the frame can be lifted up from the front. This hinge joint is designed in such a way that when the frame is closed, there can be a height clearance of 0.5" between the frame and the base to fit a book of that thickness. The frame is lifted up from the proximal end to turn the pages of the book, which is kept on the upper surface of the base. A friction type lid support provides resistance to the hinge's movement to avoid a sudden drop of the frame on the base.

Roller shades are incorporated in the frame to form the vertical window. The two roller shades were adapted from commercial window shades. They are connected using a string, which is held by a drawstring adjuster, like those used in jackets. In this manner, the user can adjust the window size by pulling or releasing a length of string. Once the size of the view window is set, the user can slide the opening along the page simply by moving the shades.

The roller shades are covered by a sheet metal case. A digital timer can be attached to the metallic roller housing at the time of use, and detached when not in use. Similarly, Mit's badge/sticker prize book can be attached to the roller housing with a magnet.

A handle is attached to the back portion of the frame, above the hinge. To facilitate transport, the user can securely attach the frame to the base using a hook latching mechanism. The device can be clamped on a table, which avoids it from sliding away from the client while he's using it.

The total cost of this device is $110.

Fig. 7.16. Client with the Reading Rainbow device.

PACK 'N ROLL

Designers: Akshay Buddiga, Aman Mittal, and Ankit Rajgariah
Client Coordinators: Victoria Guthrie, PT, and Catherine Alguire, OTR
Supervising Professors: Kevin Caves and Richard Goldberg
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INTRODUCTION

Emma is a bubbly six year-old girl with spina bifida, a congenital deformation in which the vertebral arch of the spine forms improperly. This leads to a loss of sensation in the body below the deformation, so Emma uses a manual wheelchair at school and at home. In school, Emma moves independently in the classroom and hallways with her wheelchair. However, Emma cannot operate her wheelchair and carry her belongings at the same time. She needs the assistance of a teacher to carry her notebooks, pencils, and a water bottle in the classroom and a lunch tray in the cafeteria. The client would like to be able to do these tasks independently. Commercial solutions do exist, such as removable lap trays, flip away lap trays, water bottle holders, and small detachable carry pouches. However, these products do not fit Emma's Zippie Zone wheelchair.

We developed a set of assistive devices that attach to Emma's wheelchair and help her carry her belongings independently. Three devices were developed: a removable lap tray stored on the side of the wheelchair, a water bottle holder, and a bag to carry miscellaneous items. With the devices attached to her wheelchair, Emma can still push her wheels, get in and out of the chair, and move through doorways. All of these devices are easily removable when necessary.

SUMMARY OF IMPACT

Before this device was constructed, Emma was unable to transport various objects independently while at school. Her therapist described the tray as being able to hold "mainly her lunch and…her books" and will help prevent Emma from "dropping things." The water bottle holder and bag will be very helpful because sometimes she "can't reach" her water and other miscellaneous items and must "ask someone." Emma exclaimed when describing the devices that she "can reach them now!" Finally her therapist stated, "Next year [she] will be in second grade and will be able to do all of these things for [herself]. That's so awesome."

Fig. 7.17. (a) Shows the lap tray in the storage position on the right side of the wheelchair. This position still provides her access to the wheels so that she can propel her wheelchair. To use the lap tray, the client can slide the tray forward and swing it across the chair, putting it in the position shown in (b). The storage bag is located under the left armrest.

TECHNICAL DESCRIPTION

The lap tray enables Emma to carry a variety of things, including a lunch tray in the cafeteria. It also serves as a writing/reading surface when a desk or table is not readily available. Unique aspect of the tray's design are that Emma can easily convert between a storage and a usage position by herself, and that the tray remains attached to the wheelchair at all times. In storage, the tray is hung to the right side of the wheelchair on 4″ carriage bolts that have been drilled into an aluminum bar, as shown in Figure 7.17a. The bolts hold the tray away from the right wheel of the wheelchair. When needed for use, Emma grabs the knob (shown on the right of Figure 7.17a) and slides the aluminum bar forward while simultaneously disengaging the tray's front arm from the front bolt. She then rotates the tray over her lap towards the usage position, as shown in Figure 7.19b. Notice that the knob is now below the client's left shoulder. When the tray is fully horizontal, the tray rests on the wheelchair armrests and is additionally supported by the aluminum bars on either side. The tray is held into place with a magnet on the left aluminum bar that attaches to a magnet on the underside of the tray. There is also a hole in the front right of the tray that falls onto the front bolt.

The aluminum bars are connected to polyoxymethylene (Delrin) clamps that are attached to the wheelchair armrests with countersunk screws. Polyoxymethylene is used to reduce the friction created by the sliding aluminum bars. To remove the device from the wheelchair, a parent or teacher can remove the clamps by unscrewing the cap nuts on the inside of the armrests. The clamp has a window that prevents rotation of the bar until the screws in the aluminum bar are outside of the window (which is achieved by pushing the bar forward). The tray is made of impact resistant polycarbonate—durable, relatively light, and easily cleaned. Its dimensions are 19″x19″, with a U-cutout of 8.5″x15″. It is reinforced with aluminum L-brackets on the front and sides to protect the tray if it is dropped. The edges of the aluminum are covered with Sugru, a rubbery silicone, which protects Emma and other students from the metal.

Emma will use the 8″x 9.5″ storage bag to carry items such as pencils, erasers, folders, and books. The bag is made of canvas, with plastic inserts at the opening to give rigidity to the structure. The built-in pencil pouch has a small plastic clip to hold it open for easy access. The bag is attached to Emma's wheelchair armrest with two snap fastener straps.

Fig. 7.18 The client using her lap tray at home.

A commercial water bottle holder was modified for Emma's use. The Travelon water bottle holder has an expandable pouch for different sized water bottles. A 3″ diameter PVC insert holds the pouch wide open for most sizes. Easily adjustable and replaceable zip ties allow the holder to strap on to Emma's chair behind her left shoulder. A hook attached to her wheelchair handle keeps the water bottle holder vertical and prevents it from rotating behind the chair.

The total cost of this device is $220.

THE LIGHT SABRE

Designers: Matt Lerner, Robyn Schwartzman, Henry Shen
Client Coordinator: Jeff Kallio, Coach, Mid-South Fencers' Club
Supervising Professors: Kevin Caves and Richard Goldberg
Department of Biomedical Engineering
Duke University
Durham, NC 27708

INTRODUCTION

Wheelchair fencing is a recognized Paralympic sport that was first introduced at the 1960 Games in Rome. Competitors' wheelchairs are secured to a stationary frame on the ground, allowing for upper body movement of the competitor but no back and forth movement of the wheelchair like that in standing fencing. The governing body of wheelchair fencing is the International Wheelchair and Amputee Sports Foundation (IWAS); IWAS determines the rules for competition with all three weapons, in addition to regulating the standards for equipment.

Our client, Amy, has Osteogenesis Imperfecta, commonly known as "brittle bone disease," which is a congenital disorder that affects the strength of the bones in the body. She uses a wheelchair for mobility but can lean side to side and rotate her upper body from the seated position. Though fencing frames are available for purchase, Amy currently trains without one because existing models are less than ideal for use in a practice setting. Many of these platforms are made of heavy materials that restrict portability, which does not allow for transport between the gym and local competitions. On the other hand, models that are portable are either unstable or cost-prohibitive, particularly because our client is the only wheelchair fencer at her gym. Furthermore, current models do not allow the competitor to independently secure herself into the frame and have been shown to wear down with prolonged use.

We developed a fencing frame that will allow Amy to practice with other fencers (both able-bodied and those with disabilities) in a safe manner. The platform adheres to the specifications outlined in the IWAS manual on wheelchair fencing and takes into consideration the requests of the client and her coaches. The novel design includes several features not currently included in fencing frames, such as allowing for independent tie-down by competitors, use by able-bodied fencers, and easy transport and set-up by members of the gym. The design also avoids the mechanical issues found in current models by reinforcing problem areas or changing them entirely to limit the applied strain.

Fig. 7.19. Photo of the Light Saber Wheelchair Fencing Platform.

SUMMARY OF IMPACT

The platform will "help [Amy] a lot in [her] training, especially building some core balance skills and being able to do some lunges and avoid the blade." The ease of switching between a right- or left-handed orientation was another high point for Amy and her coach, not only to accommodate various fencers, but also to help develop Amy's fencing skills and mobility. This device not only has the potential to help improve Amy's quality of life but also to make an impact on all those interested in becoming involved in wheelchair sports in the future.

TECHNICAL DESCRIPTION

The device has a rotating platform that easily adjusts for right-handed or left-handed fencers and it locks in place to the 110° measurement from the central axis required by IWAS. The platform is also adaptable for various sizes and types of wheelchairs. The tie-down systems ensure that all wheels on the wheelchair are secured to the frame and maintain their position during bouts. In addition, the straps are designed so that the competitor can tighten them independently and from the seated position. The entire platform is on tracks, which allows for easy movement to adjust the distance between the fencers. To use this fencing frame, the competitor rolls up a ramp and onto the platform from the rear, aligning her wheelchair to the tie down system. From there, the tie-down process can begin; the back and front wheels are secured, but not tightened completely. Then the platform is rotated to either the right- or left-handed position, and the straps are tightened completely. When both competitors are firmly secured, the distance between fencers can be set by moving the platform along the tracks to the desired location, and securing with a locking pin.

The rotating platform is comprised of two layers of plywood that support the weight of the wheelchair and fencer. The upper layer is circular, and it rotates to accommodate the angle of competition for either right-handed or left-handed fencers. The lower layer is a square, used to secure the platform to the track and provide support for rotation. Rotation is facilitated by a lazy Susan around the axis, and small caster wheels near the edges, that provide extra support. A pin embedded at the back of the platform locks it in the neutral, right-handed, or left-handed position and keeps the platform from turning during bouts. The two tie-down systems are also attached to this component. To keep the upper layer of the platform stable, aluminum strips are placed along the outer edge of the platform; these pieces of metal will counteract the force placed on the upper layer in bouts.

The front wheels need to be secured to eliminate any forward or backward movement and to keep the wheelchair on the frame during lunging. This is accomplished using a ratchet strap with hooks on either end. One hook of the strap attaches to the wheelchair frame, in a location that the competitor can easily reach while seated. The strap then loops under a shackle that is connected to the platform, and is passed behind the foot bar of the wheelchair to the other side, where it is looped under a second shackle and brought back up, where it hooks onto the wheelchair frame again.

There are two separate ratchet straps for the back wheels, one for each wheel. For each strap, one end connects to a vertical pipe that is mounted on the platform, adjacent to each wheel. The strap then loops through a ring that is connected to the platform, and the other end of the strap has been sewn into a large loop that the user places snugly over the top of the rear wheel. This design brings the ratchet mechanism to an accessible height to allow for easy tightening by the competitor from a seated position.

Fig. 7.20. Clients using the Light Saber Fencing Platform.

The fencing platforms rest on a pair of 11-foot long tracks. These tracks serve as both a guide for movement and a locking mechanism to keep the platform from tipping during lunging. One platform is stationary and is secured by a hole-in-pin locking mechanism that secures the platform to the tracks. The second platform can transverse the length of the tracks using appliance rollers attached to the bottom of the platform. It also locks into place using metal pins. Large wheels on the ground of both platforms add stability and increase the transportability of the device. For transporting the device, the tracks are hinged in the middle so that they can fold in half.

The platform sits just above the upper edge of the track so that an angle iron attached to the bottom of the platform runs along the side of the track. A pin attaches through the angle iron and locks into the track. This not only secures the platform in a specific lateral position, but it also aids in stabilizing the platform during lunging. The holes along the track are spaced one inch apart, and the angle iron can move in smaller increments up to one inch to allow for fine adjustments of positioning.

The total cost of this device is $465.

THE CUTTING EDGE

Designers: Vivek Patel, Eric Yuan, Tom Backeris, and Jeffery Wang
Client Coordinators: Tracey Craven, OE Enterprises
Supervising Professors: Kevin Caves and Richard Goldberg
Department of Biomedical Engineering
Duke University
Durham, NC 27708

INTRODUCTION

OE Enterprises is a local community rehabilitation program that employs people with disabilities for contract work. One of the contract jobs at this location involves cutting 24″ lengths of metal bands from a large spool of metal. The current technique requires unwinding the metal from a 120-pound spool, measuring the correct length, and making the final cut with a band saw. Because our client, Dee, has cerebral palsy, it is difficult for him to unwind and measure the metal bands because of his limited strength, dexterity, and cognitive function. Additionally, it is unsafe for him to operate a band saw from a seated position in his wheelchair.

We developed an easily operable device for our client that can unwind, measure, cut and collect 24″ strips cut to a tolerance of ½″. The device consists of three components. The first component is a feeding and measuring mechanism that eliminates the issues of physical stress and potential injury to employees from pulling sharp metal strips from the heavy spool. The second component is a cutting mechanism that employees can safely and easily operate with one arm, eliminating the need to use a band saw. In addition, there is a cut prevention mechanism that does not allow the user to initiate a cut until they have unwound exactly 24″ of metal. Finally, the third component of the device is a hands free mechanism to collect the cut strips, which requires no additional work from the client.

Fig. 7.21. The Cutting Edge Device: Above picture is the turntable and metal spool; Below picture is cutting device (a) First pipe guide (b) Rubber wheel flush on bed castor wheels (c) Second pipe guide (d) Extended lever arm (e) Sliding wooden ramp (f) Safety shield.

SUMMARY OF IMPACT

We made a visit to OE Enterprises to test the functionality of the device. Dee had a smile on his face after making a few cuts and was very satisfied with its ease of use. One staff member at OE commented that employees found the use of the device to be entertaining, resulting in a more positive and efficient work environment. Another staff member said, "This device worked very well to help Dee achieve something that he could not otherwise achieve and I think it's something that could be used by most anybody in the workshop." Before delivering our device to OE Enterprises, none of the employees could accomplish this task. Dee is very excited to begin using the device and abandon his current job of collating paper.

TECHNICAL DESCRIPTION

The overall design of the project simplifies the process of feeding, cutting, and collecting the metal strips with small amounts of force required in each step. The different components are shown in Figure 7.21. The spool of metal weighs 120 pounds. It rests on a horizontal turntable (Figure 7.22). The turntable is made of plywood and mounted on a 6" ball bearing lazy Susan, which greatly reduces the amount of friction. This allows for the band to be pulled from the edge of the reel with less than 5 pounds of force. The metal strip must be initially loaded by a staff member. Once loaded, the operator will not have to move the spool. The metal strip is fed through a guide (a) and under a rubber wheel (b). When the user rotates the wheel, the metal strip is fed through the system, into another guide (c) past the cutting shears (d), and on to an inclined wooden sliding track (e). As the metal strip is fed onto the ramp, it eventually hits the metal piece at the end of the ramp. The ramp then slides upwards as the user continues to turn the rubber tire, feeding out more of the metal strip. The ramp slides up 7" until it reaches its maximum extent where the total length of the metal strip reaches exactly 24". At this point, the user pulls the extended handle (Figure 7.21d) to cut the metal and the strip falls off the ramp into a bucket located under the base, as the ramp slides back into its original position. The extended handle decreases the force required by a factor of three. In order to prevent a cut before a full 24 inches of metal has been fed out, a metal rod attached to the ramp prevents the user from cutting until the sliding ramp is fully extended.

Three acrylic shields surround the shear blades, preventing users from accidentally getting their fingers near the blades (Figure 7.21f). Because of the feeding mechanism design, the user also does not have to even touch the sharp metal during the feeding and cutting process.

The total cost of this device is $365.

Fig. 7.22. Client with the Cutting Edge device.

UKULELE HERO

Designers: Eric Martin, Amy Peniston, Joshua Chao
Client Coordinators: Stephanie Parken, OTR
Supervising Professors: Kevin Caves and Richard Goldberg
Department of Biomedical Engineering
Duke University
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INTRODUCTION

Our client, Mia, is a 6-year old girl with pituitary dwarfism who expressed interest in learning to play a stringed instrument. Her fingers are all on the order of 1 inch in length and she has range and strength limitations in her hands. As a result, while she can produce a pinch grip, she cannot press individual strings on an instrument.

We modified a sopranino size ukulele that allows Mia to selectively hold down the strings in between the frets using the gripping force of her fingers. The device consists of five pivoting keys that can individually be depressed by pulling down on attached thumbscrews. We chose to work with a ukulele since it weighs less and is smaller than a guitar, and because it is played on the lap, it was easier for the client to hold than a violin.

SUMMARY OF IMPACT

Our advisor, an occupational therapist, indicated in a survey that she was satisfied with the overall design, and was impressed by our success in tailoring the device to fit our client's needs. She stated, "We have had to problem solve and really adapt for her finger abilities, for her stature, and her range of motion. I think it's been an awesome piece to see the design of it and the functional use of it and how she'll be able to enjoy playing music." Furthermore, our client's mother also reflected that she was very satisfied, and agreed that the team was attentive to our client's abilities and open to new ideas.

TECHNICAL DESCRIPTION

The main modification to the ukulele is the addition of spring-loaded keys, which act as capos to change cords. These are supported by a dowel and guide wire, and attached to the ukulele by connecting to a polypropylene thermoplastic chassis that is molded to the curvature of the instrument. We also added a commercially available guitar strap that fits over a custom-mounted end pin. We tuned the ukulele to an open chord, which means that strumming on all four strings produces a chord when no strings are pressed on the frets.

Fig. 7.23. Photo of the Ukulele Hero device.

The client changes the chord by lowering a key across a row of strings. This is accomplished when she pulls on thumbscrews attached to the keys at the far edge of the neck. The keys are made from Delrin plastic, and are mounted to the support dowel that runs through two mounting blocks that are fitted into the pockets of the thermoplastic cast, one at the bottom of the neck and the other at the top. Small torsion springs threaded through holes in the dowel and keys serve to raise the keys off the strings when not depressed. A guide wire runs through the mounting blocks above the dowel and prevents the keys from springing up too far, which would make it difficult for Mia to activate them. The design also includes a 23" child size strap tied through the top of the ukulele neck and affixed to a pin at the bottom of the instrument, allowing equal weight distribution so that Mia can hold it easily.

The modification acts as a lightweight interface between our client and the instrument, and is rigidly attached to the ukulele neck so as not to require removal. It is slim and durable, and can be easily carried to and from school, music lessons, or wherever else Mia would like to take it. Each key was evaluated in three trials, the result being that 88% of the time our client pulled the keys down, all the strings were hit. This allows her to play different notes easily and pursue her interest in music.

The total cost of this device is $125.

Fig. 7.24. Client with the Ukulele Hero device.

THE QUICKER PICKER UPPER

Designers: Jon Usher, Ankit Jain, Chris Radford
Client Coordinators: Laura Juel, OTR
Supervising Professors: Kevin Caves and Richard Goldberg
Department of Biomedical Engineering
Duke University
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INTRODUCTION

Tina is an adult female with facioscapulohumeral muscular dystrophy (FSHD), which is a hereditary, degenerative muscle disease. Tina has balance problems caused by leg weakness and she sometimes falls while alone at home, which is typical for individuals with this condition. The combination of her symptoms makes it difficult for her to get back up independently. Previously, she accomplished this by climbing onto her couch and then sliding into a standing position, which took her between 20 and 60 minutes, and this process was exhausting. Commercial devices available for lifting patients, such as the Hoyer lifts, are expensive and not designed to get a person from the ground to a standing position. We developed a motorized device that lifts our client from a seated position on the ground to a height of 26 ¾ inches. This enables her to slide off of the platform directly to a standing position. She can operate the device independently using a handheld controller. It requires little physical effort, and the entire process takes less than one minute. The device is firmly attached to the wall of her home office.

SUMMARY OF IMPACT

Our client, Tina, commented, "This is going to make my life so much easier. The quicker picker upper will greatly impact my life in 2 major positive ways. First and foremost, it will enable me to lift from the floor due to a fall in less than 1 minute. Due to my disability, it may take me up to one hour depending on my strength or tiredness. As a bonus, this creation will enable me to lower myself to the floor and play with my child and will allow me to be more active in the house. I am very grateful for this, thank you again!"

TECHNICAL DESCRIPTION

Our device consists of three components: the frame, the platform, and the lifting assembly, as shown in Figure 7.25. The user slides onto a platform that

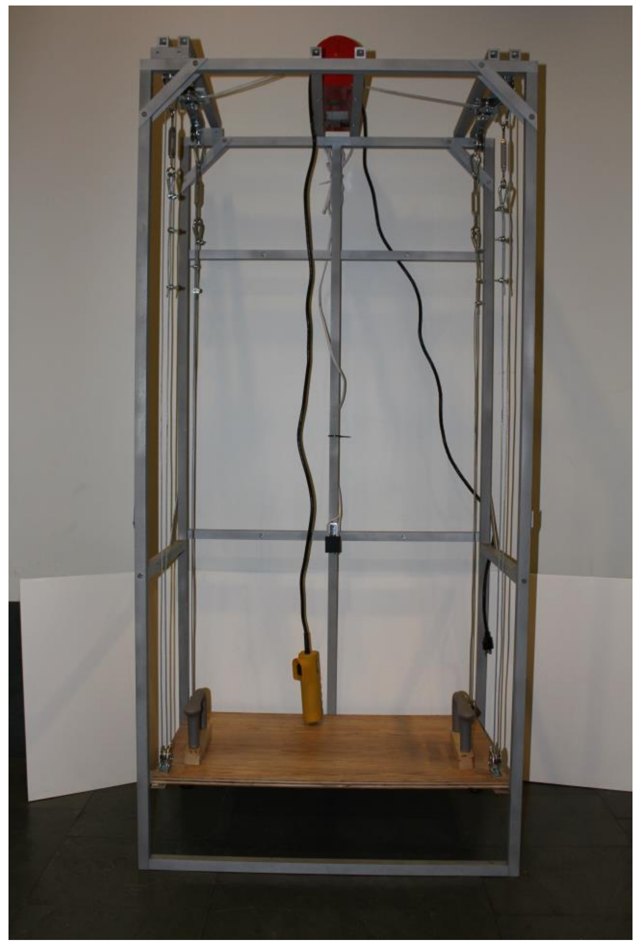

Fig. 7.25. Photo of the Quicker Picker Upper device.

rests on the ground. A handheld control allows the user to raise the platform to the desired height of about 26 ¾ inches. When the desired height is reached, a limit switch automatically shuts the motor off. The user slides forward off the platform into a standing position. Handles to either side aid the user in dismounting the platform.

The overall size of the frame is 6 feet tall, 35 inches wide, and 22 inches deep. The general shape and size of the device can be seen in Figure 7.25. Square aluminum tubing was chosen for the frame materials because it has strong mechanical properties, will not deteriorate over time, and has a modern appearance, which will match the other furniture in the home office where it is located. The platform is made of ¾" oak plywood and is 20 inches deep and 33 inches wide. The depth provides space for the user to sit comfortably and the width makes it easy for the user to mount and dismount without interference from the frame. Handles placed near the front of the platform give the user added support when transferring to a standing position.

The lifting assembly consists of four cables, guided by a series of pulleys that are attached to the platform on one end and connected to an AC winch on the opposite end. As the motor rotates, the cables wrap around the motor spindle, which shortens the length of the cables and raises the platform. We used a block and tackle pulley configuration, in which each cable wraps around a corresponding pulley, located in each corner of the moving platform. This reduces the force required to move the platform and cuts the speed in half. This gives the user greater control of their location and makes the device more comfortable. Turnbuckles were added in line with each cable to equalize the length of the four cables to ensure that the platform lifts uniformly. We chose an AC electric winch because it is reliable and can utilize the wall outlet in Tina's office.

The total cost of this device is $360.

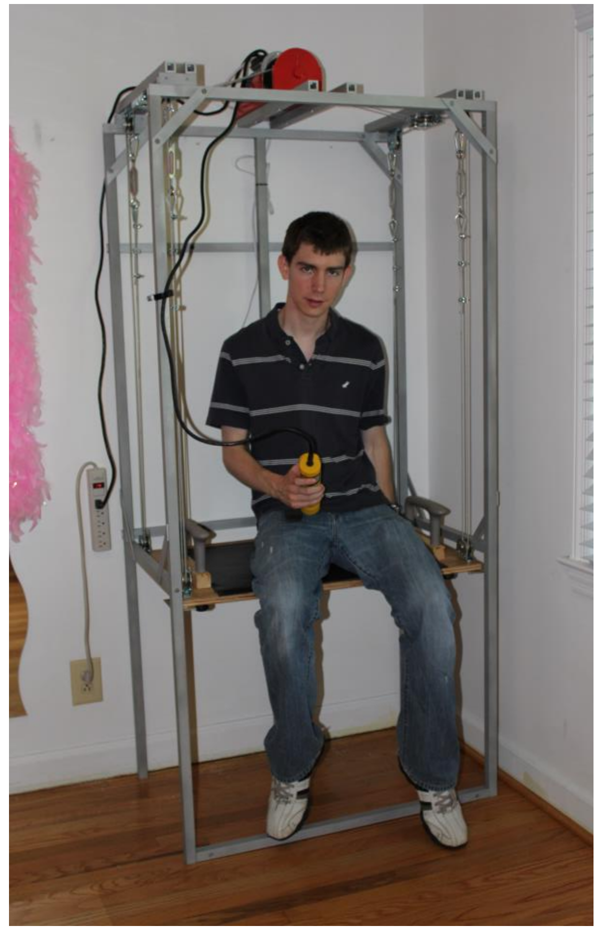

Fig. 7.26. Operation of the Quicker Picker Upper device.

CHAPTER 8
FLORIDA ATLANTIC UNIVERSITY

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ADVANCED HOSPITAL BED

Designers: Cameron Trepeck, Cole Berg
Supervising Professor: Dr. Masory
Department of Computer and Electrical Engineering and Computer Science
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INTRODUCTION

The advanced hospital bed is designed to facilitate the transport of mobility impaired patients. This will, in turn, reduce the strain on both the patient and the caregiver.

SUMMARY OF IMPACT

The advanced hospital bed is different from any other hospital bed by its capability to bring the patient to a standing position. Thus, there is no need for a nurse to carry the patient and raise him to this position. Moreover, patients that use walkers, can approach them with no help.

TECHNICAL DESCRIPTION

The advanced hospital bed operates through the combination of hydraulics and electric actuators. The bed is positioned vertically through the use of two hydraulic cylinders operated via foot controls located at the base of the bed. The upper portion of the bed is allowed to rotate 90 degrees in either direction through the use of a bearing assembly. The upper surface of the bed has three different user controlled movements: The tilting of the head and thigh sections, as well as the tilting of the entire bed surface relative to the ground (See figures). The target market of this bed would be for hospitals or rehab centers where the patient has a condition where the act of sitting up is painful or not feasible. This would allow the patient to get in and out of the hospital bed without the need to bend over. Since there is no current design that allows this ability, it seems as though the marketing potential for this product is strong.

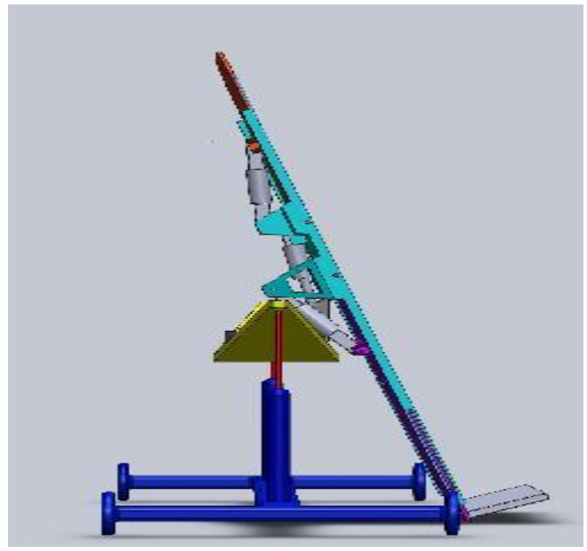

Fig. 8.1. Horizontal Rendering.

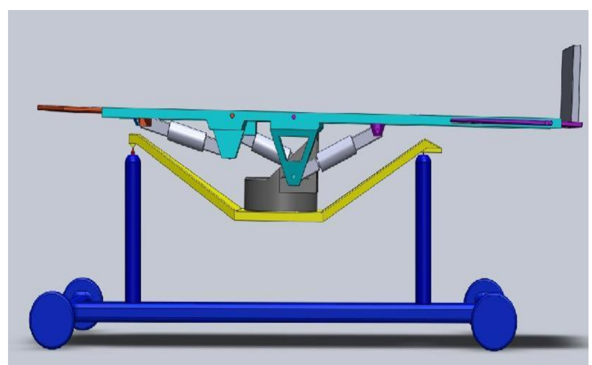

Fig. 8.2. Rendering of Chair Position.

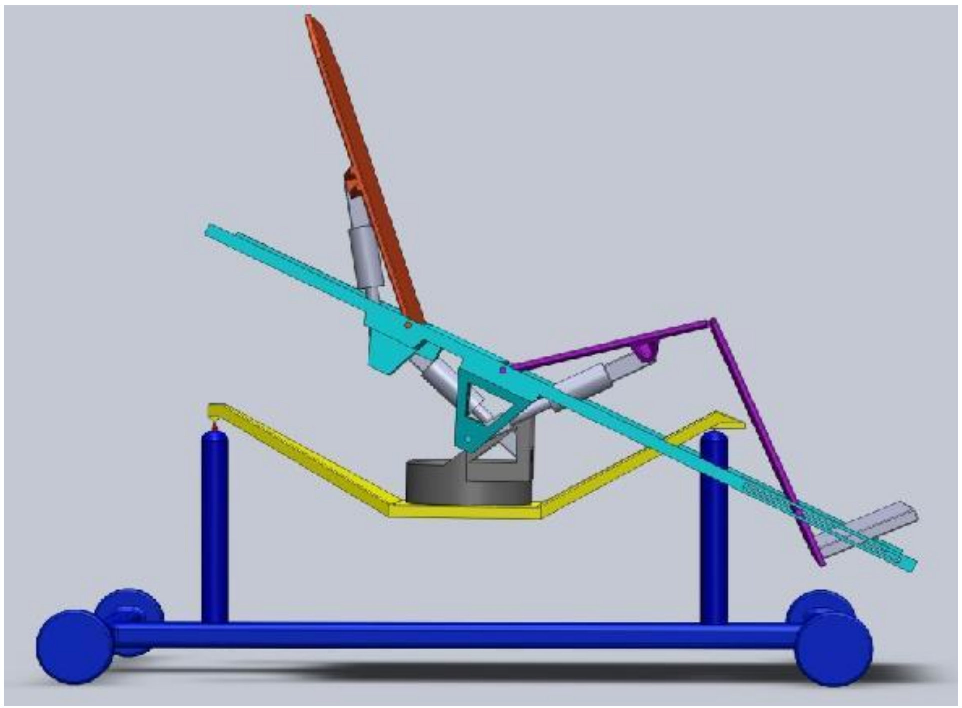

Fig. 8.3. Rendering Of Vertical Position

MEDIBOT: A IN-HOME CARE ROBOT

Designers: Rowan Hughes, Ardony Valcourt, Rafael Florez, Bredler Mortimer, and Aldez Isreal
Supervising Professor: Hanqi Zhuang
Department of Computer & Electrical Engineering and Computer Science
Florida Atlantic University, FL 33431

INTRODUCTION

When it comes to assisted living, most of the elderly and disabled would rather live in the home that they are accustomed living rather than moving into an institution specifically designated for their needs. They enjoy living in the comfort of their own home and will be able to converse with friends and family with the freedom they have always enjoyed. That is why there is a heavy need for nurses and other healthcare professionals to provide in-home care to their patients. Normally the professionals schedule regular checkups where the professionals visit the patients' home to check their blood pressure and other routine procedures. However, these visits often last but a few minutes and there a lot of time wasted in travel. That travel time could be utilized to serve patients who have a greater urgency of care.

SUMMARY IMPACT

The significance of our project is to create and easier way for doctors and nurses to interact with patients and to keep track of their conditions without having to drive to the patients' locations. This invention will help the environment because the number of nurses that will drive to a patient house just to take a blood pressure will be reduced. Nurses will not have to wait for 3 weeks just to visit a patient. While sitting at an office equipped with and computer and Internet, a nurse will be able to see 6 patients for 10 minutes each in a single hour.

TECHNICAL DESCRIPTION

The In Home Helper Robot's ability to be controlled via a web service opens up several different avenues of control. It will be able to be controlled by an application on a computer, a website, Mobile devices and anything can connect to the internet. This ability will provide substantial accessibility of the Health care professional to their patients. This approach utilizes the ubiquitous nature of the World Wide Web and adds another level of convenience.

The movement of the MEDIBOT was made possible by two 45 RPM GEARHEAD motors with wheels which require 12 volts each. To control the MEDIBOT, an H-Bridge motor control chip was used. The H-bridge operates up to 48 Volts and can handle up to 2 amps of current. It is a duo bridge which means that it can control two motors simultaneously in the forward and backward directions.

In order to dispense medications or supplements to the patient, a drawer is needed. The drawer needed to be controlled by the Health care professional. The option used was a typical cash drawer that can be found at any retail store. The tray was rigged with a linear actuator so that the drawer can open and close. The linear actuator used 12 volts and we used two relays to control the opening and closing of the drawer.

There are also various types of sensors attached to the MEDIBOT. An ultra sound ping sensor was used for collision detection. It is programmed to alert the user with a beep once an object is as closed as 48 inches from the motor. If an object is within approximately 24 inches while the robot is moving forward, it is programmed to automatically stop. The temperature Ssnsor was used to record the patient's temperature. A TTL 13.56MHz RFID reader writer was used for patient identification. When a doctor wants to verify the user's identity, the rfid tag and the web service validates the user.

An Omron blood pressure sensor was used to collect and store the systolic and diastolic blood pressure as well as the user's pulse. The web service would then access the internal memory so that the data can be stored and viewed by the health care professional. The web control panel utilized asynchronous communication using AJAX methodology between the client side control panel and the server side Web service using JSON (JavaScript Object Notation) whenever there is data that needed to be sent over the two levels. This allows us to control the robot on keyboard events and without having the page reload.

Fig. 8.4. MEDIBOT.

ELECTRIC WHEELCHAIR: IMPROVING MOBILITY FOR ELDERLY AND DISABLED

Designers: Matthew S.W. Preston II; Haakon Gangnes; Semeer Khalid
Supervising Professor: Dr. Masory
Department of Computer and Electrical Engineering and Computer Science
Florida Atlantic University
Boca Raton, FL 33431

INTRODUCTION

The purpose of this project is to design and build a wheelchair that will give the occupant a more freedom and an overall better quality of life. Current wheelchair models do not offer many options that let the occupant transfer themselves from the wheelchair to another surface, such as bed or a seat.

SUMMARY OF IMPACT

This could mean someone who is older or incapacitated would be unable to move themselves from the wheelchair to a bed or other surface without assistance from someone else. The need for this extra help can put heavy financial and personal constraints on the chair's user and their family.

TECHNICAL DESCRIPTION

In order to solve this issue, the team plans to construct a prototype for a wheelchair that will have a winch that can lift the user and move them to a flat surface such as a bed. This would give the chair's user more independence and mobility thus enabling an overall improved quality of life.

This project design is based on a prototype that was built by a previous engineering design team. While the team originally hoped to improve upon a pervious team's wheelchair design, budget and time constrains did not permit this approach. Instead, the previous team's prototype was used as a base and adapted for the new design. This strategy minimized new material costs. At the writing of this report, the chair works as planned but with the use of hand cranked rather than motorized winches due to a lack of funds.

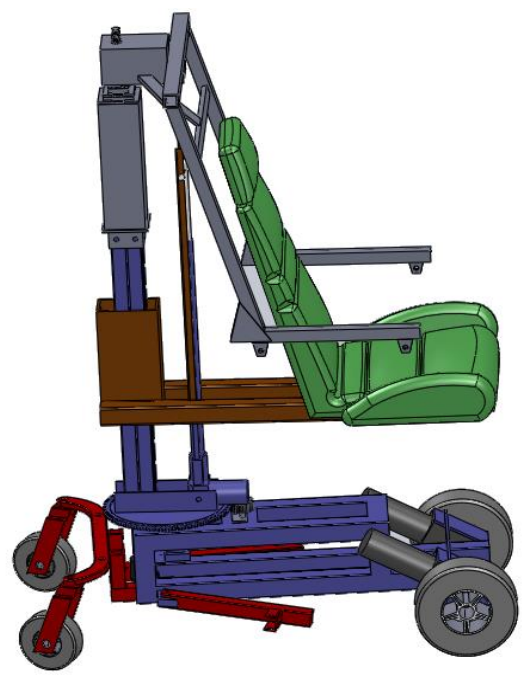

Fig. 8.5. Chair in Undeployed Position.

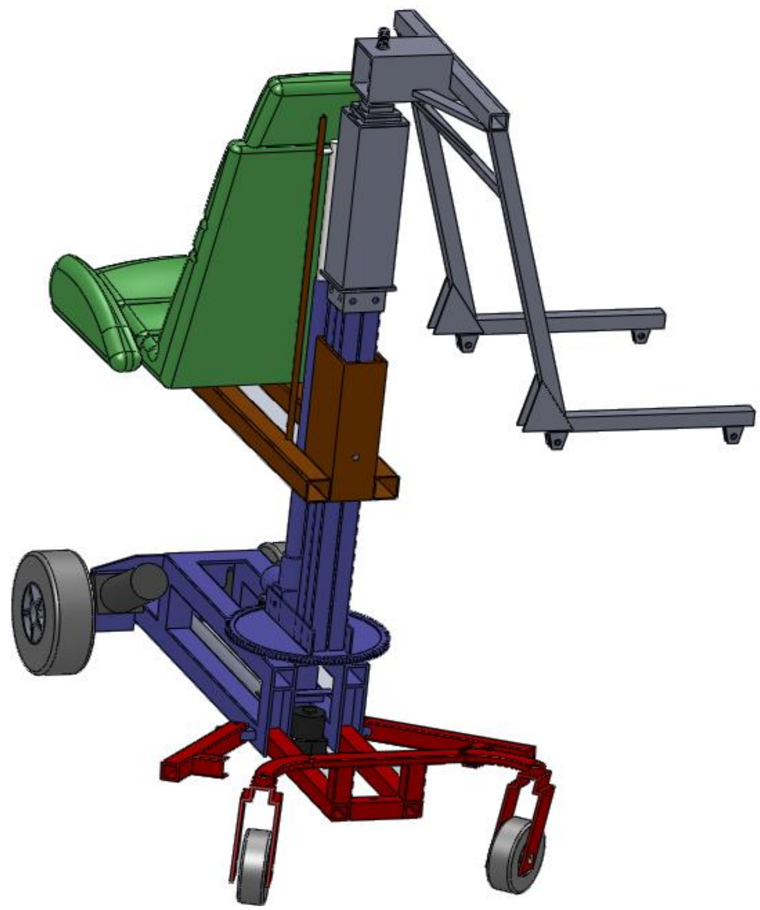

Fig. 8.6. Chair In Deployed Position.

EASY LIFT

Designers: Felipe Lachowski, M. Isabel Portal, Conor Sullivan
Supervising Professor: Dr. Masory, Dr. Salivar, Dr. Moslemian
Department of Computer and Electrical Engineering and Computer Science
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INTRODUCTION

The 'Easy Lift' is a product designed to satisfy the objective of aiding the elderly and others who are not capable of reaching objects located above average height in their kitchen areas. A product that is capable of safely transporting those who are incapable due to illness, injuries, and other debilitating conditions. This must be achieved in a safe manner in a comfortable and pleasing manner. This product was designed for the height of an average female; thus, capable of being used by the majority of the population. In doing so, maximizes the number of potential clients and patients.

SUMMARY IMPACT

The "Easy Lift" product solves a common problem encountered by millions of people. It makes them more independent and reduces the risks associated with using a typical ladder. The cost of the product is estimated at a few hundred dollars which makes it affordable to everyone.

TECHNICAL DESCRIPTION

Initial criteria that were considered in designing this product include structural weight, robustness, size, mobility, cost, and battery operation. Together, these criteria produced a mechanical lift called 'The Easy Lift'. It is simply the mode of vertical transportation with minimal effort. Achieving this however, requires several conditions to be met and standards to be considered and implemented.

Furthermore, this mechanism is capable of being transported and stored, with reasonable ease, while being able to lift two hundred and fifty pounds smoothly and steadily up to a maximum height of one and a half feet. This mechanism, 'The Easy Lift', also contains designs to account for safety and comfort features which conform to various standards. This includes the ability to lift a person vertically at low safe speeds of one inch per second. In addition, the platform contains large well-spaced internal walls of eighteen inches wide to accommodate the majority of users. Handles which meet OSHA standards, are well secured to the platform to add safety, security and comfort as the user ascends and descends.

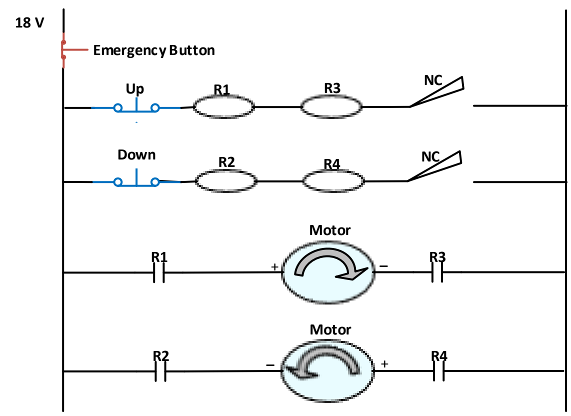

Fig. 8.7. Schematic Wiring Diagram.

These handles are also equipped with electronic switches that are used for controlling their direction; however, in the event where an unforeseen circumstance may occur, a large emergency stop switch is also mounted on the handle. Accomplishing these tasks require four relays capable of changing direction of the motor, thence, the direction of vertical motion. This design relies mainly on aluminum construction with the exception of the ball lead screw and the mobility systems.

The mobility system allows for the mechanism to be stored and transported effortlessly between areas of the home. This is due to the spring caster system which applies a force lifting the mechanism from the floor to a distance of roughly one inch; however, once fifteen to twenty pounds or greater is applied to the structure the caster system becomes deactivated. The structure is then firmly on the ground upon its slip resistant supports. Together, these features comprise 'The Easy Lift'. A three dimensional representation is show in Figure 8.8. Overall, this product provides the necessary means of transportation at the desired rate, conforms to several standards, and shows great prospect for further improvements leading to large scale manufacturing for public use.

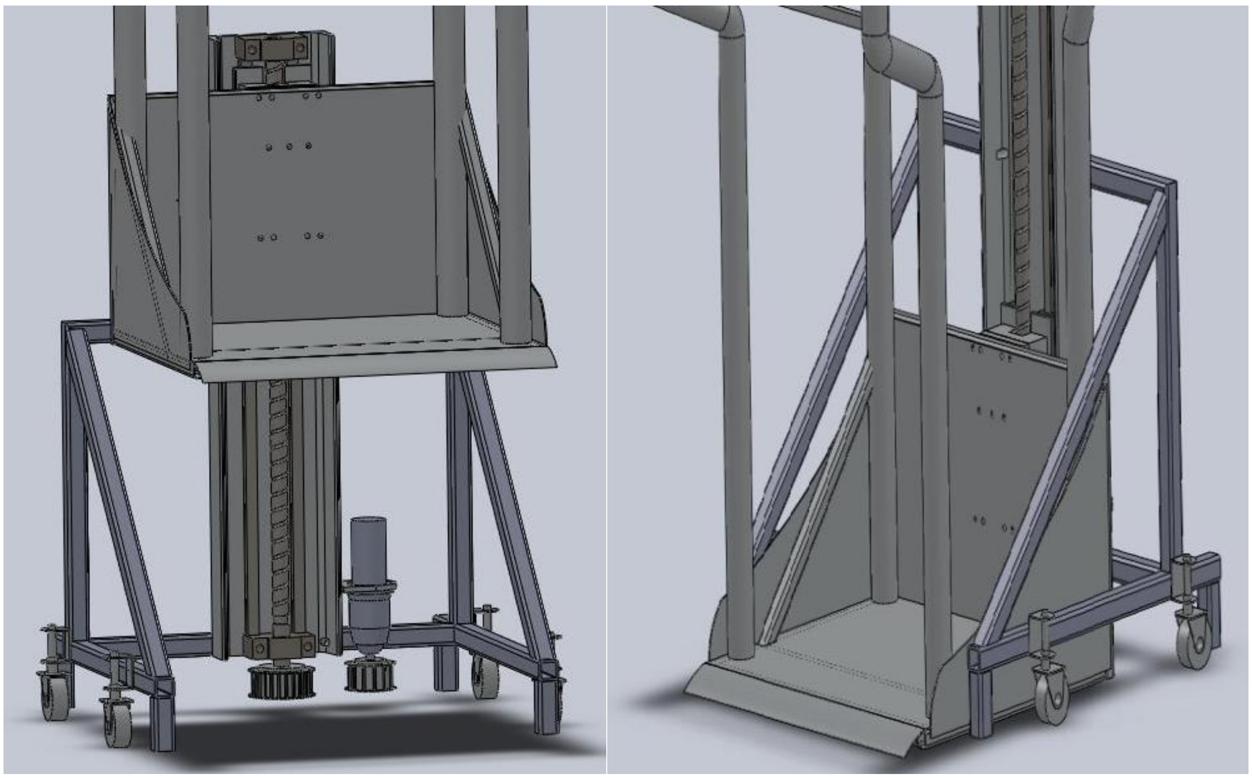

Fig. 8.8. The Easy lift.

STAIR-CLIMBING WALKER

Designers: Sabri Attalla, Inho Choi, Fahad Tarig
Supervising Professor: Dr. Oren Masory
Department of Computer and Electrical Engineering and Computer Science
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INTRODUCTION

Elderly persons are more susceptible to injuring themselves than other groups, because their health conditions have aggravated for many years. Due to their gradual losses in muscle tissues, vision sight, and hearing capability, the elderly are challenged in carrying out their daily life routines. To overcome or to facilitate the challenges, they need supportive aids which can help them. Conventional walkers assist elderly persons in walking on a flat surface. However, these walkers are inadequate in ascending or descending a flight of stairs due to the stair's geometry. Therefore, a safer walker that can be utilized in ascending or descending a flight of stairs is designed for elderly persons.

SUMMARY OF IMPACT

This stair-climbing walker enables elderly persons in ascending or descending a flight of stairs and can also be utilized in walking on a flat surface. The walker has a brake mechanism that assists in preventing elderly persons from falling while operating the mechanism. It is designed to be used on any staircase.

TECHNICAL DISCUSSION

The stair-climbing walker (Figure 8.9) is mainly composed of two 4-wheel assemblies, one brake mechanism, and one main frame. To construct a 4-wheel assembly, the team needed four aluminum bars in dimensions of 20″x1.00″x0.25″, four lightweight wheels in diameter of 3 in, one guiding block in dimensions of 5.56″x5.56″x0.5″, eight slotted sliders in dimensions 1.00″x5.00″x0.188″, two spacer in a diameter of 0.56″ and height of 0.75″ and another two space in a diameter of 0.56″and height of 1.00″. To get started constructing the walker, most of the required components were fabricated from raw materials and obtained by dissembling a commercially available product that has the required components.

The geometry of each staircase may vary one from to another. However, the design constraints for staircase geometry have been determined from the Florida Building Codes and that aided in finding a proper geometry of 4-wheel assembly bracket and wheel size. For that reason, holes were bored into specific positions of the bracket to accommodate the wheels and slotted sliders. Each two bars were welded at their mid-point, forming a cross, because the 4 leg brackets facilitate the movement of the stair walker. On a surface of the inner bracket, four spacers were installed so that the guiding block, which has a x-shaped groove, can be mounted.

The main frame is made of a 1/2″diameter stainless steel pipe. It is bent resembled to a reverse U. The main frame is reinforced by welding diagonally crossing structural rods. Each end of the main frame is bent in such a way that it can slide freely in the groove of the guiding block. Moving the main frame ends along the grooves, rotates the 4-wheel assembly. For the brake mechanism, a gear and pawl are installed between the two 4-wheel assemblies. The gear and pawl are held by crossing-rods. A brake handle is installed near top end of the main frame. The brake cable connects the brake handle and the pawl. Thus, when the brake handle is grabbed, the pawl pivots around its rotating axis to lock in the braking gear.

When the stair climbing walker is utilized on a flat surface, it is used as a conventional walker. When the stair-climbing walker is utilized for ascending or descending a flight of stair, the first two front wheels of the stair climbing walker must be in contact with the rise of the stair. Once it is in contact with rise of the stair, the main frame can be maneuvered along the guiding groove to rotate the wheel assemblies forward. Each time the main frame is utilized to rotate the wheel assemblies; the slider and brake wedge prevent the stair walker from being pushed backwards and reduces the risk of falling down the flight of stairs.

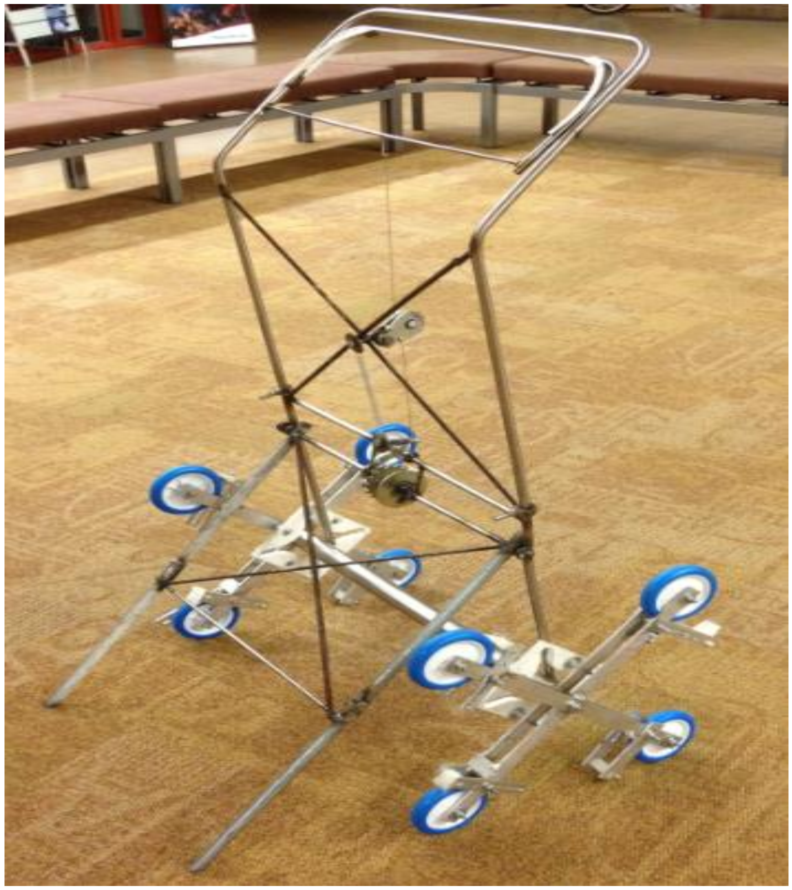

Fig. 8.9. The Structure of Stair-Climbing Walker.

GPS TRACKER FOR ALZHEIMER'S PATIENTS

Designers: Mariangie Castro, Joanmanuel De Jesus
Supervising Professor: Hanqi Zhuang
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INTRODUCTION

Alzheimer's patients very often become disoriented in time and space. In fact, one of the early signs of this disease is getting lost in their own neighborhood and not being able to find their way home. As this disease progresses, the patient becomes more vulnerable and often a caretaker is assigned. If the caretaker is a nurse, it will be expensive and if caretaker is a family member, it will be life altering. The GTAP was created to help the caretaker keep track of their patient. GTAP is a GPS enabled device that is connected to a website to make the tracking easier.

SUMMARY OF IMPACT

This device will keep track of the Alzheimer's patient whereabouts at all times. In fact, the GTAP will give the patient the opportunity to maintain their privacy, remain confident and preserve their independence, something many patients with this progressive disorder lose. This device will also help families by giving them the security and guarantee that their loved ones are just one click away.

TECHNICAL DESCRIPTION

The GTAP prototype (see Figure 8.10) includes two parts, the first is the console and the other is attached to the belt. We would have preferred to have both parts in the belt buckle but due to time and expense constraints, this was not possible.

The console consists of the Arduino Mega Microcontroller, the GSM module with Shield, the GPS module and the photoresistor. The Arduino Mega Microcontroller board is based on the ATmega2560. It has 54 digital input/output pins of which 14 can be used as PWM (pulse width modulator) outputs, there are also 16 analog inputs, 4 UARTs, 16 MHZ crystal oscillator, USB connection, power jack, ISCP header and 256 KB of built in flash memory. This enabled us to connect all the required components, and direct the traffic from the GPS module, photoresistor and accelerometer module to the GSM module. The EM-406A GPS module chipset, receives data constantly to acquire the person's GPS location. The latitude and longitude is extracted along with the time and sent via another module, the GSM module.

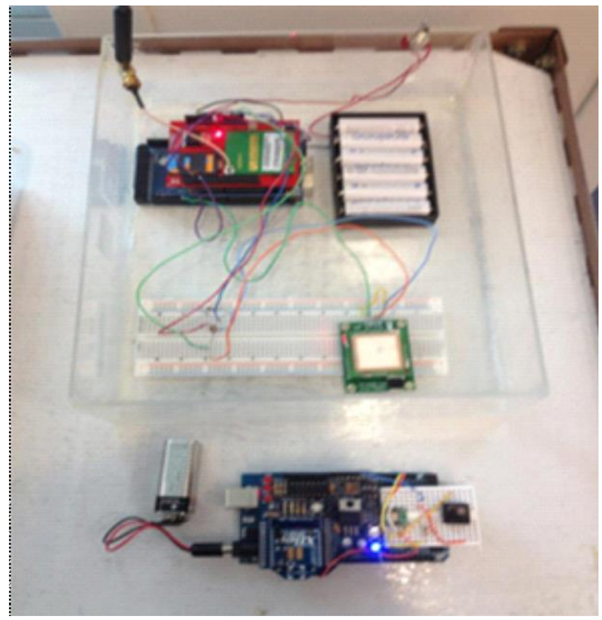

Fig. 8.10. GTAP Prototype.

The GPS module is connected via a 6-pin interface cable to the Arduino Mega Microcontroller. In addition to the GPS, we also included a photoresistor to obtain the person's well-being. If a GPS lock cannot be acquired and the location is dark, the patient has a predetermined amount of time to cancel an alert which will be sent to the software side of the project for dangerous conditions. The photoresistor always outputs the signal received from the location where the patient is and forwards it via the GSM module to the software side. Lastly, the SMS5100B is a miniature, quad-band GSM 850/EGSM 900/DCS 1800/PCS 1900 module. This module is used to transmit the data from the microcontroller to the software side of the project via GSM/GPRS and TCP/IP.

The hardware attached to the buckle consists of the Xbee wireless module, the Accelerometer with built-in temperature sensor for jerk detection and buttons. The accelerometer gives the patient's orientation. It measures the person's acceleration and orientation in perspective to the ground environment. If the accelerometer reads very fast jerk then the patient is given a predetermined amount of time to cancel the alarm. The accelerometer also measures tilt, collision, static and dynamic acceleration, rotation and vibration. In addition, this accelerometer has a chamber of gas with a heating element in the center and four temperature sensors around the edges.

The GTAP also has a software side to demonstrate all the data that we are getting from the hardware. Once all the data is received from the sensors handled by the Arduino Microcontroller it is then forwarded via the GSM module and saved into a database within the Python server.

The Server PC handles all incoming traffic from outside the internet and GSM data. We created our database on the open source MySQL RDMS holding the following fields of data: latitude and longitude (from GPS), photoresistor field and accelerometer automatic fall detection field. Ultimately, there is a GTAP website that incorporates all the data computed by the web servers and displays it in a user friendly manner.

The approximate total cost for parts of the GTAP device including AT&T data service plan is $750.00.

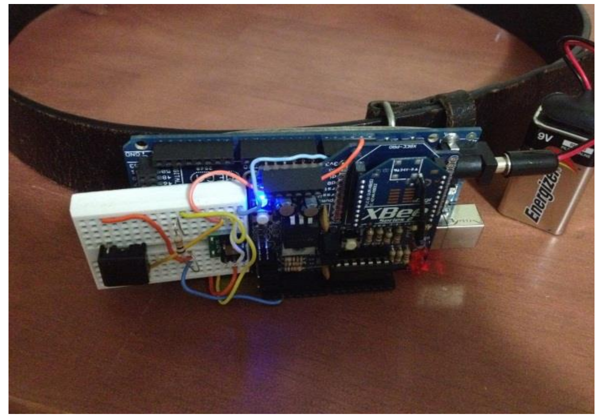

Fig. 8.11. GTAP WIRELESS BELT PROTOTYPE.

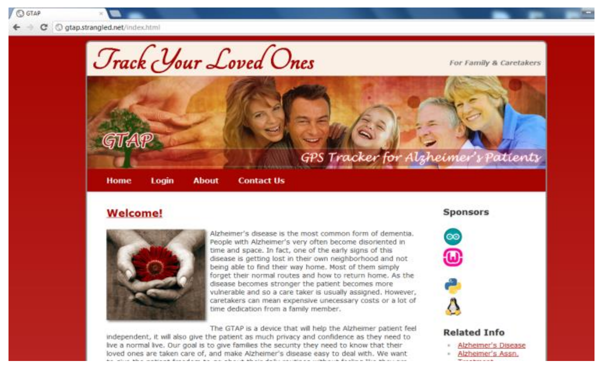

Fig. 8.12. GTAP Website.

MOBILITY ASSIST DEVICE FOR TRAVERSING STEPS

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Supervising Professor: Dr. Hanqi Zhuang
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INTRODUCTION

Wheelchair access to some locations is still limited. An example of this is older private structures with steps leading up into the entryway. Traversing these obstacles can be challenging, especially when an assistant has limited strength or endurance. Surmounting a simple obstacle such as a short run of steps or steep hill have typically called for the person in the wheelchair to be bodily carried up and down, or more dangerously, carefully rolled across the obstacle hoping not to slip. This places undue stress on the assistant and reduces the dignity of the person requiring the wheelchair. The proposed device allows for an assistant to easily transport a person in a wheelchair both up and down steps or hills, while still allowing for the normal operation of the wheelchair once the obstacle is cleared.

SUMMARY OF IMPACT

The device allows for the transport of a person in a wheelchair up and down steps or steep inclines. The device is intended as an aide to an assistant who would provide for stability and a human awareness of possible tipping danger, which maximizes overall occupant safety. The device would provide the 'muscle' to traverse the obstacle allowing the assistant to focus on the comfort and safety of the rider. Once the obstacle is overcome, the device then reconfigures, becoming a normal manually operated wheelchair. This would be advantageous when attending a private function or ceremony.

TECHNICAL DESCRIPTION

The overall device was built to be half scale in size. This made the overall project more affordable and allowed for safer testing and evaluation. The wheelchair traction apparatus (Figure 8.13) is mounted in an aluminum frame to keep the overall weight as low as possible. The frame also employs an anti-back-tip device that does not allow the wheelchair to exceed a tilt back of 23^{o}. The drive tracks are primarily a low durometer rubber, similar to tennis shoes. This allows the friction obtained to be sufficient to travel up or down most surfaces. The tracks are reinforced with Kevlar for strength. Attached to the frame are all the drive axles, motors, batteries and a deployment mechanism with electronics bay.

The deployment mechanism is of a scissor-screw jack hybrid design similar to that found in a car seat. The motive force is derived from separate electric motors that allow the deployment mechanism to take the weight of the wheelchair as well as shift the center of gravity relative to the traction frame. This ability to change the center of gravity increases the overall stability and safety of the device.

Once the system is deployed, it is driven by a pair of motors via a drive chain and sprocket. The entire operation is controlled via a wireless controller which can either be used by the assistant, or the person in the wheelchair. The wireless controller is operated using a single command button, like that of a wrist watch. The commands are displayed on a large screen and provide information on the wheelchair performance such as relative tilt angle, battery capacity, deployment mode and throttle position. The wireless controller also provides alarm indication in the event of dangerous tilt angles or traction device overload.

The device has an onboard 2.5AH 24V battery as its primary source of power. A second extended range battery (2.7AH) can be added to the front of the traction frame for extended use. The device was tested with occasional step climbing for 8 consecutive hours using only the standard onboard battery. This is considered more than enough time of use for social gatherings or other similar uses.

Should the wireless system be incompatible with the rider, for example if there is a concern over a pacemaker, then the device may be controlled via a wired controller that simply plugs into a port located in an easily assessable location under the electronics bay.

The prototype device has been successfully tested with a 40 lb. payload going up 11^{o} steps with a maximum device angle of 22^{o}. The cost of the prototype device is approximately $1,000.

Fig. 8.13. The Proposed Wheelchair Allowing the Transport of a Person Up and Down Steps.

TELEOPERATED ROBOTIC ARM VIA KINECT

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Department of Computer and Electrical Engineering and Computer Science
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INTRODUCTION

The purpose of our design project is to provide an interface that is capable of wireless control of a robotic arm using 3D-positional data output from the Microsoft Kinect, as well as using supplementary data from a "Sense" glove that will house various sensors. The Sense glove enhances fine-point control of the end effector of the robotic arm, which in our case, is a claw. While our programming is based on a specific robotic arm, the real value of our programming is its portability. We intend that, with a few modifications, our control interface can be applied to any sort of robotic arm design.

SUMMARY OF IMPACT

Our design provides intuitive control for robotic platforms; this can be quite beneficial for individuals that have poor motor functions, due to advancing age. The ability to allow a robotic device to perform functions that the individual cannot perform while retaining the same motions is quite useful. It allows ease of use for complex machines that usually require complex control methods that take time to learn.

TECHNICAL DESCRIPTION

After establishing a basic description of our design, we can go into the finer details. The components that are incorporated into the “Sense” glove include: flex sensors (resistance changes based on bend), an accelerometer, an Xbee wireless module, and Arduino Nano microcontroller and a vibrational motor. These sensors provide the data on the user’s hand and wrist motions, this data is then sent via the Xbee RF module to the computer. The vibrational motor is used to give the user tactile feedback; when the robotic arm grips an object a small vibration is felt that is proportional to the gripping force.

The other sensor used to read the user’s motions is the Microsoft Kinect. The Kinect is a sensor array that includes a color camera, infrared projector, and an infrared camera. The infrared components are used to calculate depth; this combined with the color camera allows the Kinect to track a user in 3D space. We use this data to map the location of the user’s arm and control the robotic arm to follow its movements.

Fig. 8.14. Teleoperated Robotic Arm – System Components.

All of the sensor data is processed on a computer through a Windows application we programmed. The program allows the user to see the view from the Kinect camera, adjust the camera position, see the data points being read, as well as the angle data being output to the arm. The program calibrates a starting position of the user’s hand as a reference and will control the robotic arm to follow the user’s hand from this origin.

While the range of motion is limited by the hardware of the robotic arm used, the arm used in this project can follow the user’s movements up to 10.25 inches from the origin and lift up to 13oz. The overall cost for this project was approximately $600, the most expensive component being the robotic arm itself.

Fig. 8.15. Sensors: Kinect (Top) and Control Glove.

WHEELCHAIR LIFT FOR PARAPLEGIC DRIVERS

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Supervising Professor: Oren Masory
Department of Ocean & Mechanical Engineering
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INTRODUCTION

One percent of the world's population is wheelchair bound and in need of accessible transportation to enable more freedom. The purpose of this project is to provide paraplegic people with full independence when entering or exiting a vehicle, with the possibility of storing the wheelchair on the vehicle. The vehicle chosen for this project is a van. For this purpose two mechanisms were designed, the first one is responsible of lifting the paraplegic person from his wheelchair to the driver's seat. This mechanism is attached to the roll bars inside the van. The second mechanism, called the wheelchair holder, is responsible of storing the wheelchair on top of the van's roof. This mechanism is attached to the roof rails of the van. These two mechanisms allow the paraplegic drivers to easily access the vehicle's driver seat, regardless of the height of the vehicle.

SUMMARY OF IMPACT

The wheelchair lift for paraplegic driver mechanisms enables the users to use their vehicles freely without the need of anybody else to help. This would impact directly their independence and would take paraplegic people many steps closer to having a normal life.

TECHNICAL DESCRIPTION

The wheelchair holder mechanism shown in Figure 8.16 was made of a box, big enough to hold the wheelchair, which rotates around a rod that is attached to two bearings, in addition to an actuator and a winch. Initially the box is at the horizontal position. The actuator is used to move the box from this position to a vertical position and back, this actuator provides 400 lbs. of force with a maximum extension of 24". The winch is responsible for lifting the wheelchair to the inside of the box for storage, and lowering it back to the ground. It provides a full force of 2000 lbs.

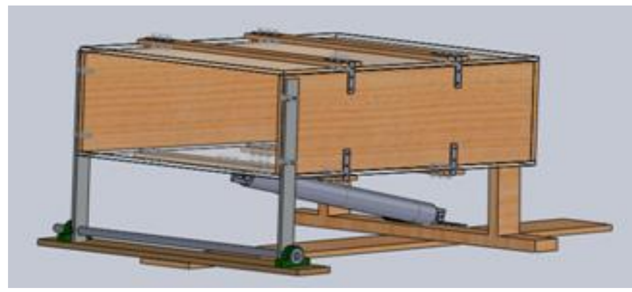

Fig. 8.16. Wheelchair Holder Mechanism.

For the rail mechanism shown in Figure 8.17, the principle components are a rail, a sliding bar, a support, an actuator and a winch. The support simulates the roll bars of an actual van, to which the rail is to be attached. The sliding bar is connected to the rail using two rollers. The actuator is responsible of moving the sliding bar in and out of the van's cabinet. The winch allows moving the paraplegic person vertically, while the actuator moves the user horizontally. The winch used for this mechanism is similar to the one on the wheelchair holder mechanism, however this actuator provides 250 lbs. and has a maximum extension of 30". The winches were bought with the controls included. For the actuators, a 4 channels control device was used to allow the control of both actuators using only one remote. All the electrical components on this project require a 12V input, which can be provided by the van's battery.

Fig. 8.17: Rail Lift Mechanism.

Fig. 8.18. Wheelchair Lift for Paraplegic Drivers.

CHAPTER 9
LOUISIANA TECH UNIVERSITY

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LOW-COST ADJUSTABLE PROSTHETIC LEG

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INTRODUCTION

The overall goal of this device is to create a low cost, adjustable, and durable transtibial prosthetic limb for children in developing countries. Pediatric prosthetics must be replaced every six to twelve months as a result of the quick rate at which children grow (Strait, 2006). Current solutions providing low cost prosthetic limbs to persons with transtibial amputations do not account for the growth of the individuals. Current solutions utilize one pylon systems or complete prosthetic leg systems, which have to be fully and completely replaced when the child outgrows the system (Barnes, 2010). The adjustable prosthetic limb system we designed provides a long-term solution while still fitting the needs to be durable, low-cost, high strength, and easily available ("Trans-Tibial" 2006).

SUMMARY OF IMPACT

This device will enable a child to use a prosthetic leg for years at a time, eliminating the need to travel to clinics or overseas for fittings for new prosthetic legs. The caregiver can loosen the bolt on the clamp and adjust the prosthetic to the length of growth of the matching limb. This design allows the child to use one pylon system for a 10 year period. The International Council for the Red Cross (ICRC) currently provides low cost, short-term solutions, but the adjustable prosthetic limb system provides a long-term solution. This device could potentially replace existing products the ICRC uses.

TECHNICAL DESCRIPTION

The device is an adjustable prosthetic leg, consisting of an adjustable pylon system and a carbon fiber resin composite (CFRC) foot. The pylon system adjusts for growth from 9.5in to 16.5in. It uses a clamp system to hold the 2 industry-standard pylons together. The growth range supports children from ages 7 to 17 years old and supports a maximum weight of 300lb.

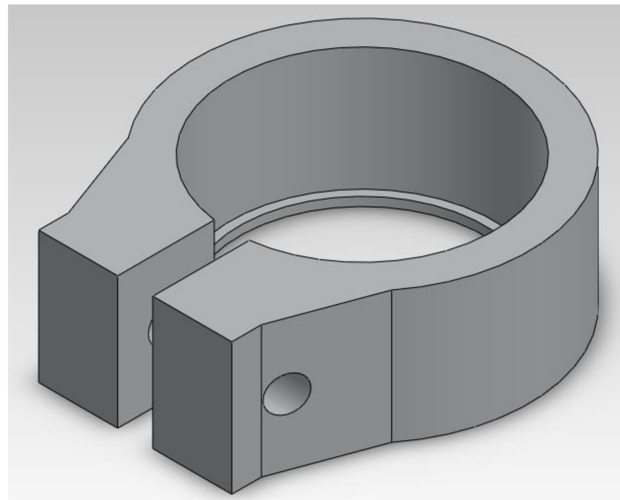

Fig. 9.1. The bolted clamp model.

The adjustable pylon system contains 2 standard aluminum 6061 pylons, machined to fit standard socket and pyramid adaptors. The system also contains a bolted clamp, which holds the 2 pylons in place at the length desired. The bolted clamp can be seen in Figure 9.1. The bolt on the clamp can be loosened and tightened using an Allen wrench to adjust the length of the pylon.

The CFRC foot contains a c-shaped heel and is modeled after current U.S. models for prosthetic feet. A medium density foam core is printed using a single axis routing machine. The foot is made by soaking the foam core in a 20-minute hardener and resin combination. A double layer of 19.7 ounce-per-square-yard fiber and 60-minute hardener-and-resin combination is applied and molded to the foam core after the foam core becomes adhesive. A second layer of fiber is laid immediately following the molding of the first. The foot holds a maximum weight of 330lb and has 10.7° of flexion. This process enables us to create a foot that supports the maximum required weight while still allowing flexion of the foot. The entire assembled prosthetic system can be seen in Figure 9.2.

The total cost of our entire system is approximately $162US.

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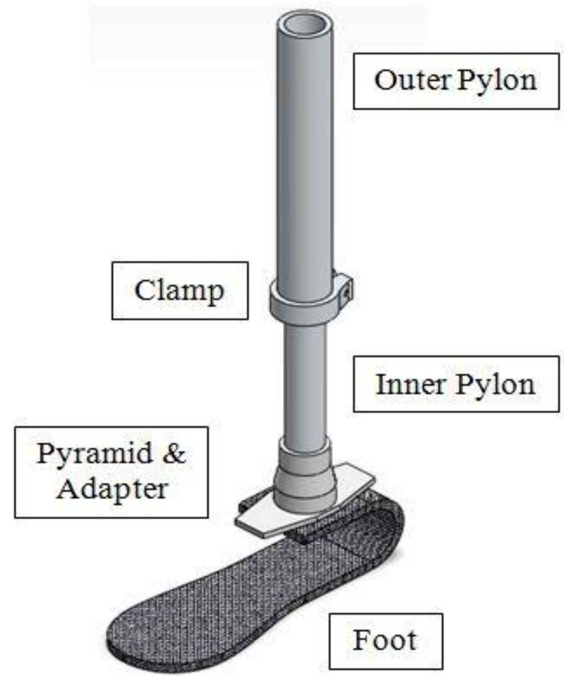

Fig. 9.2. The entire assembled system.

AUDIBALL: A TONE EMITTING BALL FOR THE VISUALLY IMPAIRED

Designers: John Dighton, Sierra Irwin, Andrew Macaluso, Aawaz Shrestha
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Introduction

The Louisiana Center for the Blind (LCB) is a facility to help persons with visual impairments to fully participate in the economic, social and spiritual lives of their communities. There is an increasing interest in baseball as a sport among the members in the Louisiana Center for the Blind. Currently, there is a baseball team using a Beep Baseball (http://www.nbba.org/) for the game. The Beep Baseball, however, does not last very long during the game. Also, the existing product makes a beeping sound instead of making a constant tone, which is very difficult to track while playing. Moreover, the ball's center of gravity does not lie in the center of the sphere; therefore it does not perform like an actual baseball. Desiring an improved ball, the Louisiana Center for the Blind approached us as a senior design group to design a baseball that would overcome the existing flaws of the Beep Baseball without compromising the safety of the players.

SUMMARY OF IMPACT

A design of a better sound-emitting baseball is desirable in order to allow persons with visual impairments to play baseball. The AudiBall consists of three main parts: an electronic component, a skeleton made out of ABS plastic, and a layer of viscoelastic material as the outermost shell. It is designed to emit a constant tone and withstand high impact forces. As a result of this project, everyone can enjoy the game of baseball irrespective of a visual imparity.

Technical Description

The AudiBall consists of three main components. The inner core electronic component produces a constant tone, which helps visually impaired people to keep track of the ball. Spherical shaped ABS plastic skeleton is a protective housing for inner core electronic component. In addition, it provides

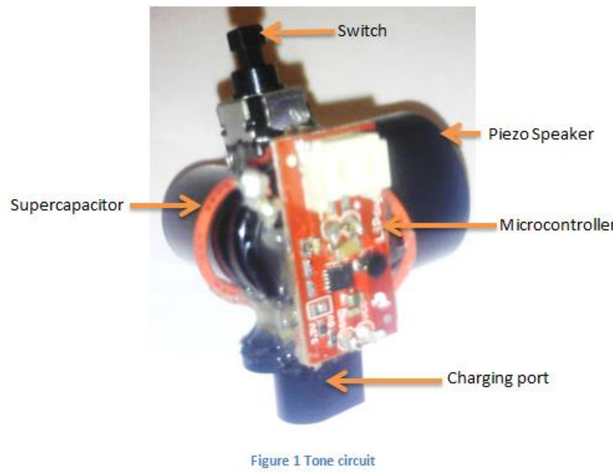

Fig. 9.3. Tone Circuit.

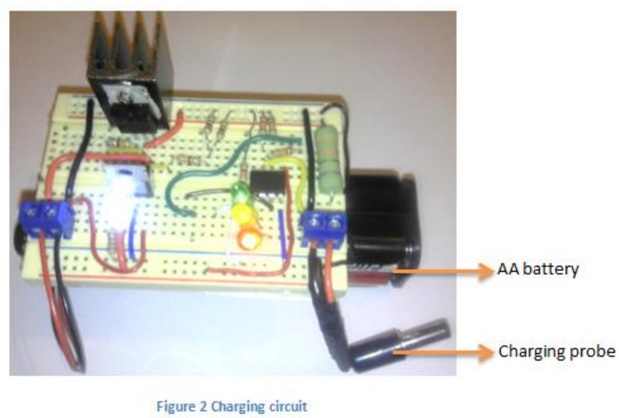

Fig. 9.4. Charging Circuit

original spherical shape for the AudiBall. The outermost layer is made out of viscoelastic material for soft feel, and high impact resistance.

The AudiBall electronics are simple, lightweight, and is design to withstand the high impacts. The tone circuit (Figure 9.3) is designed with the fewest number of components possible: a piezoelectric speaker unit for constant tone, a switch for activation of the circuit, a super capacitor for powering the circuit, and a small plug for charging the power source. The ideal power source for the ball is a super capacitor, due to its low weight and maintenance, long life, lack of harsh chemicals, and resistance to shock, heat, and moisture. A custom charging circuit (Figure 9.4) is designed consisting of four pairs of standard AA batteries and a microcontroller to monitor the charge.

It is important to protect the inner core electronic component, while simultaneously retaining the original spherical shape of the baseball. Acrylonitrile Butadiene Styrene (ABS) is used as the plastic skeleton because of its high impact and thermal resistance, manufacturability, economic viability, and product availability. The ABS plastic skeleton is spherical in shape and consists of several acoustic holes (Figure 9.5). These holes help in transferring the sound to the outside of the ball. Eight pieces of the AudiBall are printed using a rapid prototyping machine. These pieces are glued together using adhesives that perform well under high impact.

The outermost layer of the AudiBall is exposed to the environment. Considering the safety of the players and the softness of the ball, viscoelastic material is chosen to be the best fit for the outermost layer of the ball. The outermost layer is made such that the holes are not covered, further maintaining the acoustics of the AudiBall. A viscoelastic material (Dragon Skin® 20) provides softness to the AudiBall and helps to dissipate energy during the collision of the bat and the ball, thus increasing the life cycle of the ball.

The total cost of this project is US$370.

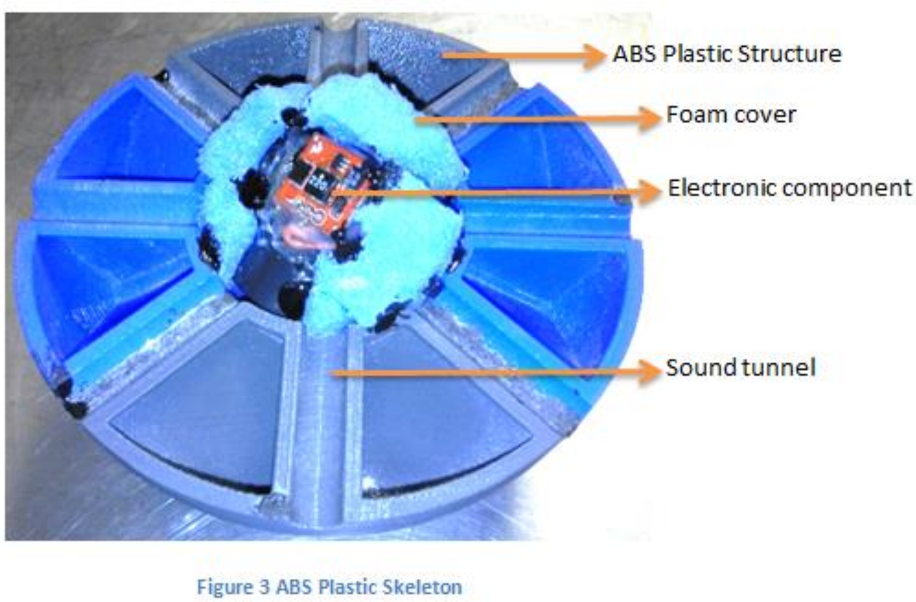

Fig. 9.5. ABS Plastic Skeleton.

THE EASY PLUG: MAGNETIC ELECTRICAL OUTLET ADAPTER

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Supervising Professor: Dr. Patrick O'Neal
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INTRODUCTION

Individuals with arthritis or Parkinson's disease experience limited upper-body strength, limited dexterity, poor coordination and tremors of the hand. These physical constraints can make it difficult and unsafe to plug in electrical devices. Several devices and patents exist for mechanisms that will reduce the force or coordination needed to make a proper electrical connection; however, these designs do not reduce force and coordination simultaneously. The Easy Plug (EP) was designed to minimize the strength and coordination needed to plug appliances into electrical outlets. The device can be seen in Figure 9.6. This project improves upon a previous generation from senior design last year. The improved design 1) incorporates a guide system which reduces the coordination needed to connect the two adapters, 2) makes internal connections for stability and safety and 3) reduces the size of the device. The final device will require minimal force to use, comply with electrical safety standards, and fit into a standard American 3-prong outlet.

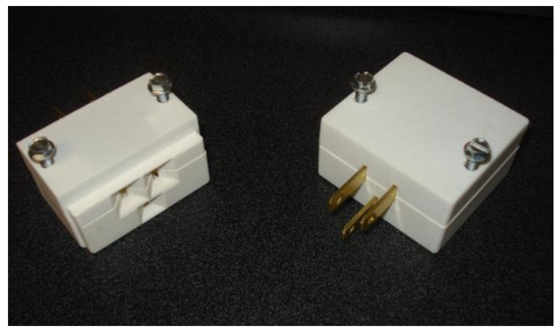

Fig. 9.6. The Easy Plug.

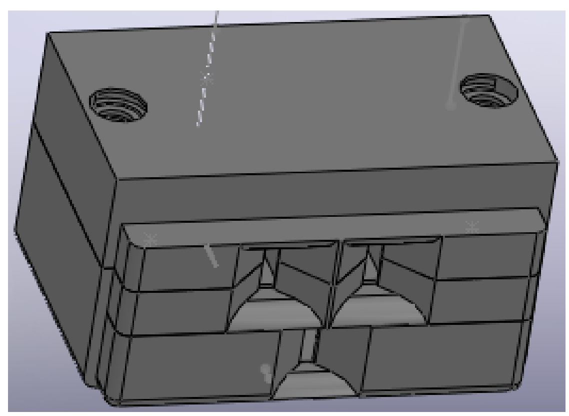

Fig. 9.7. The Wall Adapter Receptacles with Their Guide System for Pin Insertion.

SUMMARY OF IMPACT

The device is specifically designed to help individuals with disabilities or diseases that limit upper-body strength, coordination, or dexterity. Individuals with these physical constraints often depend on others to assist them with daily activities. As a result, these individuals seek devices that help them regain independence. EP users find that the device makes plugging in appliances easier and feasible for them.

TECHNICAL DESCRIPTION

The design consists of two adapters: a wall adapter and an appliance adapter. The wall adapter houses a male bridge and wiping contacts connected by 14-gauge solid copper wire. The wiping contacts receive the male blades housed in the appliance adapter. The male blades and their receptacles (openings on the wall adapter face with wiping contacts behind them) were placed in a triangular fashion that mimics the prong placement of a 3-prong plug. The triangular placement and distances between the pins are standard. The appliance adapter also houses the female bridge that connects to the male blades via 14-gauge wire. Each part is 120V/15A rated or higher.

The parts' ratings allow the parts to be used in standard American home outlets.

The device design incorporates a guide system around the receptacles that receive the male blades of the appliance adapter. The guide system reduces the coordination needed to connect the two adapters. The guide system can be seen in Figure 9.7. Neodymium magnets are used to help reduce the force needed to connect the adapters and make a proper electrical connection. The magnets are placed behind the two adapters' interfaces in order to bring the adapters together. The fully-assembled device only requires the user to install the wall adapter and the appliance adapter for use.

The size of the previous design was reduced. The dimensions of the updated wall adapter and appliance adapter are 1.180 in. x 2.107 in. x 1.390 in. and 1.180 in. x 2.103 in. x 1.938 in., respectively.

The internal parts are industry standard parts; none were soldered together. Each part is 120V/15A rated or higher. The parts' ratings are in compliance with the National Electric Code (National Fire Protection Association, 2010), which allow the parts to be used in standard American home outlets. The internal components were insulated with heat shrink for added safety. The male blades fit snuggly into the openings of the appliance adapter. Furthermore, the male blade of the appliance adapter used to connect to ground protrudes more than the other two blades. This design allows the ground of the appliance to electrically connect first. The layout of the electrical parts in the ABS plastic housing can be seen in Figures 9.8 and 9.9. All of these parts are housed in ABS plastic, which is an excellent insulator. The use of these particular parts contributes to the overall device safety.

Child-proof mechanisms are incorporated into the device design. The magnets are placed so that the two adapters repel each other if a user attempts to incorrectly connect the two. When connected correctly, the magnets hold the two adapters firmly together. The magnets are strong enough that the two adapters cannot unintentionally disconnect and cause an arcing event.

The electrical components incorporated in the new design connect internally rather than externally and were designed to fit each other to reduce the possibility of arcing. The electrical components also have an increased surface area connection, which means the electrical connection is more stable.

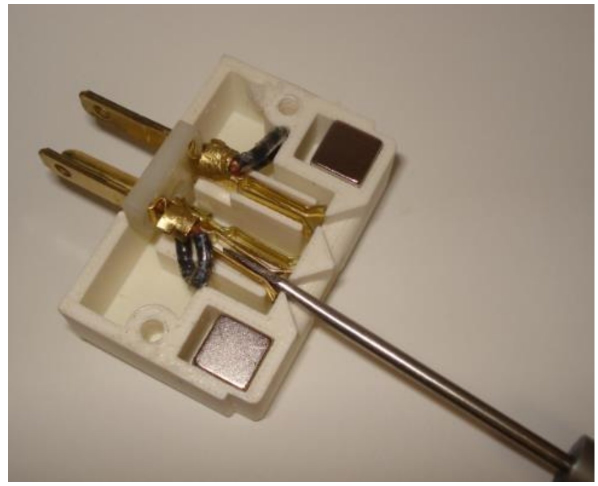

Fig. 9.8. Internal View of the Wall Adapter.

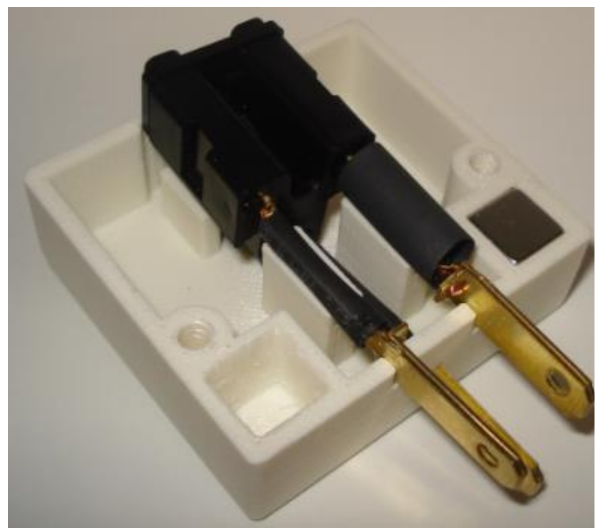

Fig. 9.9. Internal View of the Appliance Adapter.

The cost of parts and materials was about $135.

THE i-CHAIR: A THOUGHT AND EYE MOVEMENT BASED Wheelchair Drive Control System

Designers: Chelsea Dressel, Jessie Theobalds, Osayd Sawalha, Ryan Romance, Titly Dhar & Zakariae Yerrou
Mentors: Dr. Alan Chiu and Marty Gallagher
Biomedical Engineering Department
Center for Rehabilitation Engineering, Science & Technology (CREST)
Louisiana Tech University, Ruston, LA 71272

INTRODUCTION

More than 230,000 individuals in the United States live with some form of paralysis. More than half of these individuals use electric wheelchairs for mobility. As a result, several electric wheelchair drive control systems have been developed to cater to the preference or degree of immobility of wheelchair users. The three most popular wheelchair drive control systems used are: 1) joystick controls, 2) head array controls, and 3) sip n' puff controls. These drive controls all require considerable physical effort for operation, and individuals with high level quadriplegia may experience difficulty with everyday use. A drive control system that allows a person to navigate an electric wheelchair using thoughts and eye movements is designed to minimize the physical effort needed for operation. The system uses a headset designed by Emotiv (Figure 9.10) to collect brain and eye signals. These signals are processed through programming and are converted to voltages that direct the wheelchair in four different directions: 1) left, 2) right, 3) forward, and 4) reverse. The development of the i-chair drive control is intended to improve the quality of living by establishing greater ease of mobility.

SUMMARY OF IMPACT

The i-chair drive control is designed to cater to the mobility needs of individuals with high level quadriplegia. These persons will benefit from a drive control that requires minimal effort for operation, eliminating the regular need for assistance from other individuals. The primary impact of this thought-and-eye-movement-based drive control is an increased sense of independence and mobility for its users. Marty Gallagher, manager for the Assistive Devices for Independent Living program at CREST, stated that a well-developed system will also be attractive to individuals who have less severe forms of paraplegia. The i-chair drive control system could serve as a replacement for other drive control technologies, improving the quality of living of persons with paraplegia.

Fig.9.10. Emotiv headset.

TECHNICAL DESCRIPTION

The i-chair drive control is composed of three major parts: 1) the EPOC neuroheadset from Emotiv, 2) the LabView programs, and 3) the NI-USB-6210 data acquisition device (DAQ) from National Instruments. The neuroheadset is used to detect raw electroencephalograph (EEG) and electrooculograph (EOG) signals from the user. These signals are processed using LabView graphical programming. A classification matrix discerns four distinct signal patterns and assigns them to four distinct Boolean commands. These commands send voltages of ± 1.25V to the DAQ's two analog outputs to control the movement of the wheelchair.

The Ranger Storm II electric wheelchair from Invacare is used for the drive control application. The chair uses two main control systems: 1) the joystick controls and 2) the controls for the chair motors. Power sent to the joystick control is converted to voltages of positive and negative 1.25V and runs through two wires to the motor controls (Figure 9.11. The i-chair drive control is designed to input the same DC voltages at the wire terminals of the chair motor controls to mimic the deflection of the joystick.

The DAQ and wiring are enclosed in an 8-inch by 6-inch by 4-inch ABS plastic electrical enclosure box; the output wires of the DAQ run into the joystick control enclosure of the chair. A USB cord runs from the DAQ to a laptop, which is necessary to run live LabView programming.

The i-chair drive control system has a total response time less than one second and a response efficiency of above 80%. This response efficiency must improve to approximately 100% before the product can be seriously considered for commercial or consumer testing. Further development is necessary to improve the system efficiency and reduce the number of components required for operation.

The cost of designing the i-chair prototype is about US$900, which includes US$299 for the Emotiv headset.

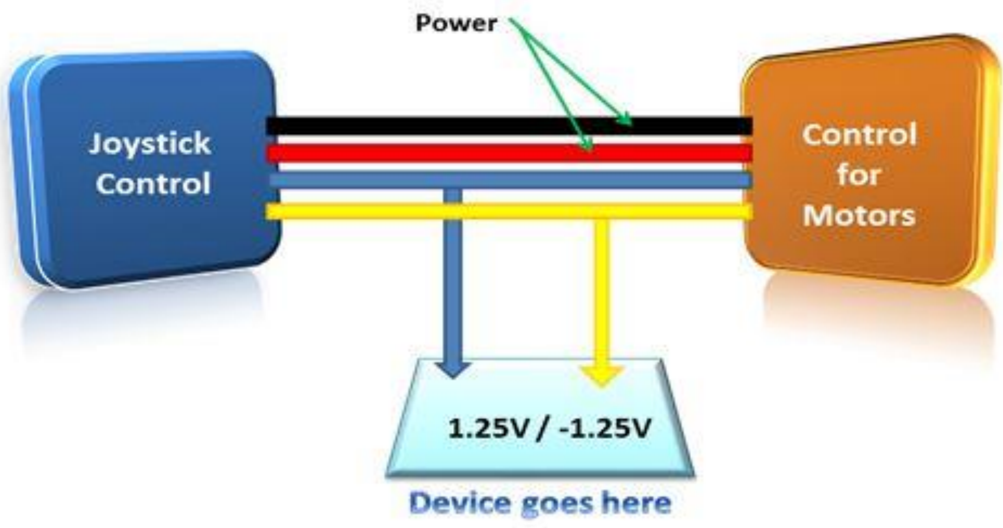

Fig. 9.11. Drive Control.

RAMPED UP

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Supervising Professor: Hall, David E. – Ph. D.
Mechanical Engineering Program Chair
Louisiana Tech University, Ruston, LA 71270

Introduction

The purpose of the device is to aid in the decision-making process before purchasing a new vehicle and installing a mobility accessibility device for a vehicle (Figure 9.12). The intent is to design and build a simulation device that will be kept at the Center for Rehabilitation Engineering, Science and Technology (CREST) facility. The simulation device will be able to imitate the various grades of ramps on mobile accessibility devices installed in vehicles. The target angle measures for design criteria are 7.1°-9.6°. The ramp can have a maximum width of 30” and a length of 60”.

Fig. 9.12. Two common wheelchair accommodations: side entry (top) and rear entry (bottom)

Fig. 9.13. Welded platform frame

Summary of Impact

Vehicle customizations are extensive and involve replacing the doors and floor of the vehicle as well as adding electric motors and ramps. The decision of which vehicle and mobility accessibility device to purchase is currently made on a prediction of individuals’ abilities. This requires the individual to make an assessment of his or her needs. However, the individual is rarely able to accurately assess his or her needs. There is a need to be able to measure the abilities of the individual, so that he or she may be properly paired with a mobility accessibility device before making the purchase. This simulator gives CREST the capability to accurately measure a patient’s capability to climb targeted ramp grades.

Technical Description

The simulator design is comprised of 4 basic components: platform, frame (Figure 9.13), legs (Figure 9.14), and ramp.

Figure 9.14. Platform frame with leg.

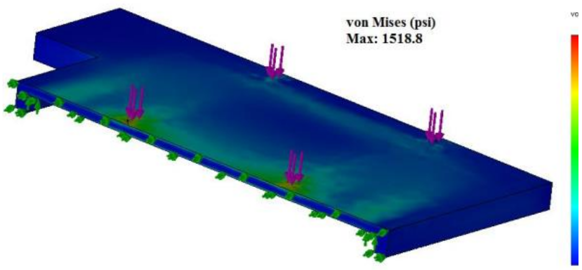

Fig. 9.15. FEA Analysis of platform.

The platform is a composite design that was built by sandwiching a foam core between a fiberglass skin. The platform has adjustable legs that attach to a frame, and the frame is fastened to the platform. The legs and frame are bolted to the platform by the mounting plates imbedded in the core. Various platform, frame, and leg designs are modeled using SolidWorks's finite element analysis to determine which design has the highest strength-to-weight ratio (Figure 9.15). The platform is used in conjunction with an EZ-Access Advantage Series suitcase ramp for accessibility.

The simulation device is adjustable in height by 4 vertical legs with retractable power screws. The total vertical range of the legs is 2.75". Bed liner is sprayed over the top surface of the platform to provide a protective and rough surface. Adjustable and fixed railings are laid across the platform to restrict the movement on the platform surface. The railings imitate the space in which an individual can move inside specific vehicle with a mobility accessibility device installed. The railing is designed with Velcro to quickly adjust the workable surface area on platform. Figure 9.16 shows the completed platform with the suitcase ramp.

Fig. 9.16. Platform with Suitcase Ramp.

The total cost for this project is US $708.

CHAPTER 10
NORTH DAKOTA STATE UNIVERSITY
(ECE Dept.)

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HAND TO SPEECH

Designers: Mohammed Albalawi, Davis Beattie, and Stephen Farnsworth
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INTRODUCTION

Hand to Speech is an easy-to-use device that converts American Sign Language into text. An intelligent glove, shown in Figure 10.1, uses flex sensor and accelerometer data to identify hand position. When hand position matches a known sign, the corresponding text is transmitted wirelessly to a computer for display or text-to-speech conversion.

Hand to Speech is simple to use and affordable, which makes it useful for the hearing impaired as well as those who are learning sign language. To operate the device, the user puts on the glove, turns on the power, and then begins signing. By utilizing cost-effective sensors and components, Hand to Speech is more affordable than many similar devices.

SUMMARY OF IMPACT

According to ASLinfo.com, there are over one-half million deaf or hearing impaired people in the United States and Canada. Considering this fact, many people can benefit from the technology of Hand to Speech. Firstly, the device can be used as a communication device. Individuals can use Hand to Speech as a means of communicating in the way they are most comfortable with, as opposed to conforming to hearing-centric communication methods. Secondly, Hand to Speech can be a useful tool to learn American Sign Language (ASL). To illustrate this concept, the popular and highly effective Rosetta Stone language learning system employs a user-input aspect that allows learners to correct their pronunciation. Similarly, Hand to Speech could be used as a user-input device for an ASL learning program. In this way, Hand to Speech would provide ASL learners with real-time feedback regarding the accuracy of their signs, thereby allowing them to perfect their signing capabilities.

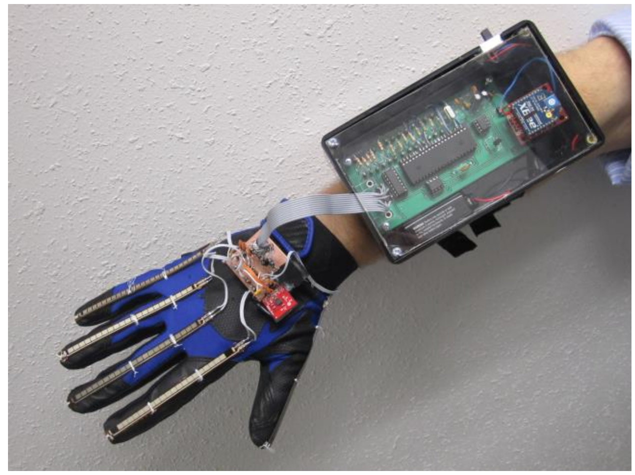

Fig. 10.1. Hand to Speech Glove Unit.

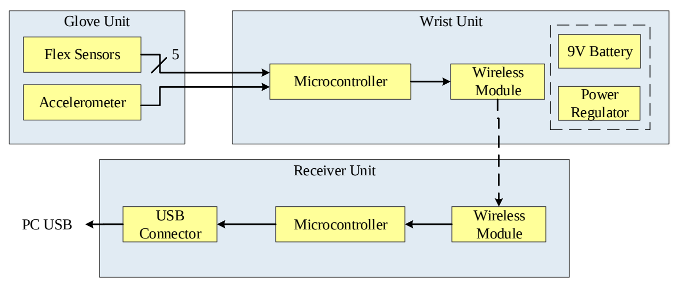

Fig. 10.2. Hand to Speech Block Diagram.

TECHNICAL DESCRIPTION

As shown in the block diagram of Figure 10.2, Hand to Speech has three primary components: 1) a glove unit, 2) a wrist unit, and 3) a receiver unit. The glove unit includes five flex sensors and an accelerometer. The wrist unit includes a microcontroller, a wireless module, and a power supply. The receiver unit contains a wireless module, a microcontroller, and a female USB port.

Flex sensors are attached on the outside of a comfortable glove, one along each finger. These flex sensors are connected to a small printed circuit board (PCB) which also includes a three-axis accelerometer. Ribbon wires connect the glove sensors to the wrist unit and provide power from the wrist unit to the accelerometer.

On the wrist unit, a microcontroller uses an on-board analog-to-digital converter to digitize accelerometer and flex sensor data. Flex sensor data establishes finger position while accelerometer data establishes hand orientation. Finger position is needed to classify all letters. Some signed letters, such as "G" and "Q" shown in Figure 10.3, differ only in hand orientation. In these cases, successful letter identification also requires the accelerometer data. To identify letters, the microcontroller consults lookup tables that specify ranges of sensor data that are unique to each character. Ranges are kept small enough to minimize misclassifications but wide enough to accommodate natural variations in signing motions. Once the microcontroller identifies a signed letter, the corresponding ASCII character is sent to the wireless module for transmission to the receiver unit.

On the receiver unit, a wireless module receives the ASCII characters sent by the wrist unit. A USB-enabled microcontroller formats the received ASCII characters for keyboard-style USB transmission to an attached PC. In this way, character data is accepted on the PC in any place that permits text, such as a document or text box. The Hand to Speech system also includes a key feature to remove incorrect or unwanted letters. The user can simply twitch her or his hand in a counter-clockwise direction to trigger a single backspace, thereby erasing the incorrect letter.

The overall design of Hand to Speech proved to be a success with the potential to be a marketable product. The cost to build Hand to Speech is slightly over $250. The transition to surface-mount parts would result in smaller enclosures and would reduce cost. Mass production of the units could further reduce costs through the economies of scale. Even at $250, however, the overall cost is reasonable in comparison to other language learning tools, such as the Rosetta Stone.

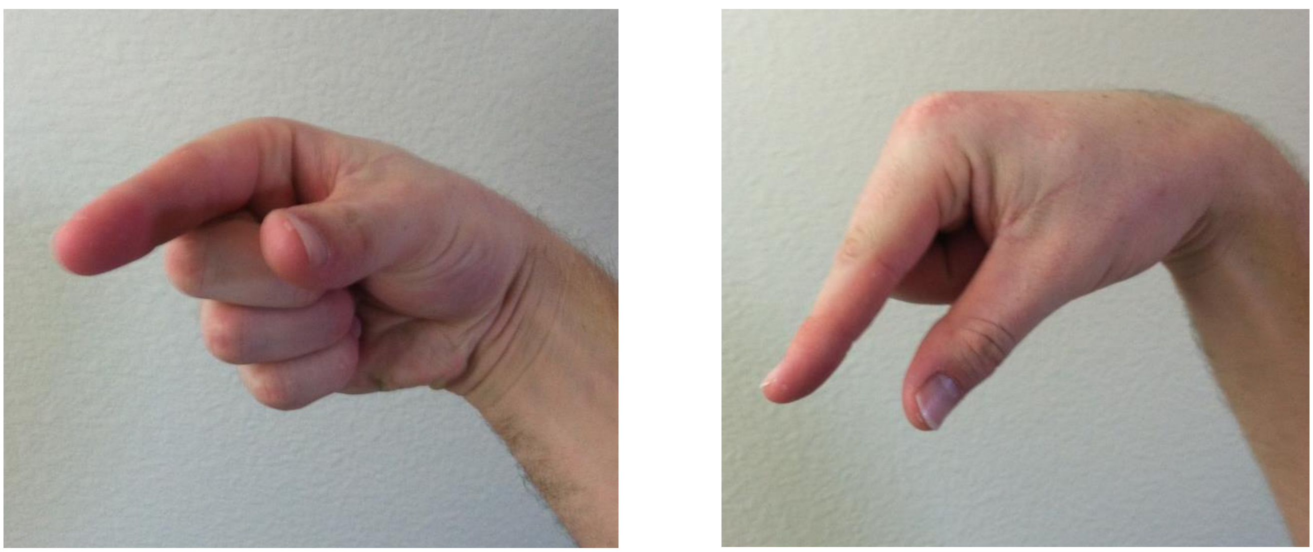

Fig. 10.3. ASL letters "G" (left) and "Q" (right).

STETHOSCOPE FOR THE HEARING IMPAIRED

Designers: Vishwajeet Chhikara, Brandon Hacker, Yuting Lin
Client Coordinator: Val Tareski Ph.D.
Supervising Professors: Mark Schroeder Ph.D., Val Tareski Ph.D.
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INTRODUCTION

The client is a home health nurse with hearing aids. Each day at work, she uses a stethoscope to monitor the vital signs of her patients such as heartbeat, blood pressure, and breathing sounds. In order to perform these tasks, she needs to remove her hearing aids, put in the stethoscope, take her readings, and then reinsert her hearing aids. The client desired a device that would allow her to take these readings without removing her hearing aids.

The Stethoscope for the Hearing Impaired converts sounds produced by the stethoscope into an electronic signal and sends it to the client's hearing aids wirelessly via a relay device designed by the hearing aid manufacturer.

SUMMARY OF IMPACT

The Stethoscope for the Hearing Impaired allows the client to take vital signs without having to remove her hearing aids. In addition, volume is easily adjusted up or down using two buttons. The device connects to any Bluetooth enabled headset, which is a convenient feature.

TECHNICAL DESCRIPTION

As shown in Figure 10.5, the Stethoscope for the Hearing Impaired consists of five main components: 1) stethoscope head, 2) microphone, 3) amplifier, 4) microcontroller, and 5) Bluetooth module.

The Stethoscope for the Hearing Impaired contains a cardiology stethoscope head. This stethoscope head is single sided and gives a different frequency response based on the pressure applied. Firm pressure results in a better high frequency response for breathing and blood pressure sounds. Lighter pressure gives a better low frequency response for sounds such as heartbeats.

Embedded within the tubing of the stethoscope head is an omnidirectional electret microphone. The microphone is powered by a 9V battery and has a current limiting resistor.

Fig. 10.4. Stethoscope for the Hearing Impaired.

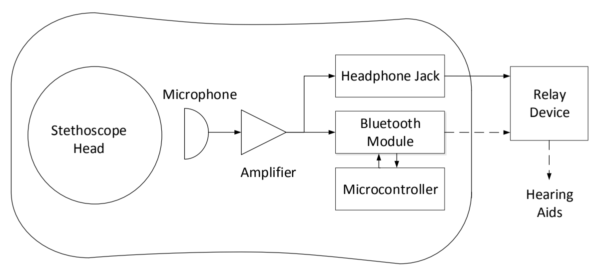

Fig. 10.5. Device Block Diagram.

The signal from the microphone is amplified using an LM386 audio amplifier. For this application, the gain is set at 20 to match the input range of a Bluegiga WT-32 Bluetooth Module. The amplifier circuit also contains a capacitor from the power pin to ground that blocks DC noise. The amplified signal is output to the audio input pin on the Bluetooth module.

The Bluetooth module is controlled by an ATmega328 microcontroller. The microcontroller monitors three pushbuttons that initiate pairing, volume up, and volume down functions. A fourth pushbutton resets the microcontroller.

To pass audio from the Bluetooth module to an external headset, the two devices must first be paired. In device pairing, the microcontroller issues a sequence of four commands: 1) inquiry, 2) pair, 3) call, and 4) SC0 open. Figure 10.6 illustrates the pairing process. To begin, the microcontroller sends the inquiry command to the Bluetooth module. This command instructs the module to scan the immediate area for the addresses of other Bluetooth devices. The microcontroller reads these addresses and stores them for future commands. Next, the microcontroller issues the pair command. This command initiates a pairing between the Bluetooth module and the external headset. The microcontroller then sends the call command to the Bluetooth module to establish a headset profile connection. Finally, the SC0 open command opens the audio channel and allows audio to be sent from the Bluetooth module to the headset.

Two buttons connected to the microcontroller allows users to adjust the gain of the audio signal. When the buttons are pressed, a pointer either increments or decrements through a lookup table that contains gain values for 24 preset levels that range from -24 dB to 42 dB. Whenever the pointer changes, the corresponding gain value is sent to the Bluetooth module using the set control gain command. The default gain of the module is 0 dB.

The cost of the Stethoscope for the Hearing Impaired is approximately $130, which includes $80 for the Bluetooth module, $20 for the stethoscope head, $20 for the enclosure, and $10 for the remaining components.

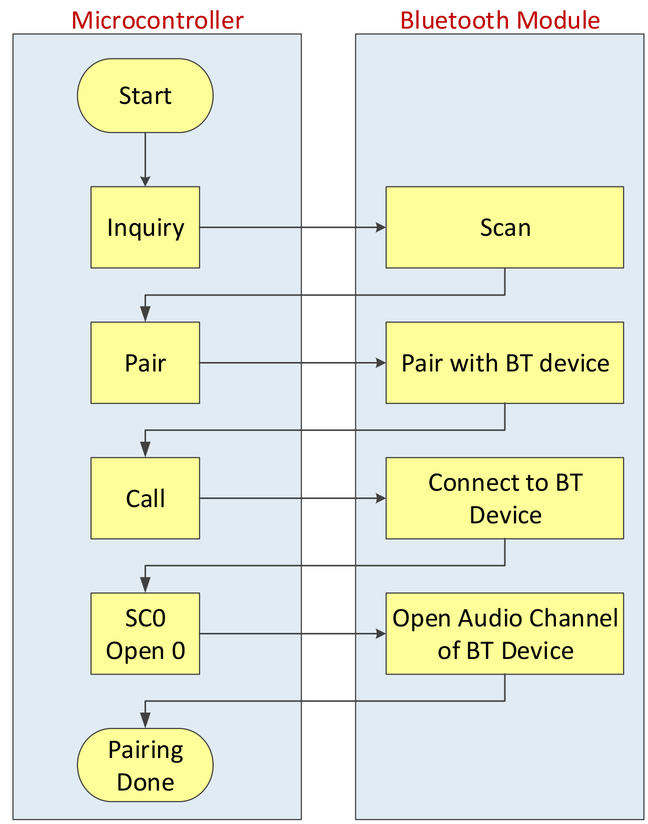

Fig. 10.6. Pairing Process.

ENVIRONMENTAL CONTROL UNIT

Designers: Eric Hagen, Andy Wendroth, and Sushanshi Gupta
Supervising Professor: Dr. Mark Schroeder, Ph.D.
Electrical and Computer Engineering Department
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INTRODUCTION

The environmental control unit (ECU) is a wheelchair mountable device that allows wireless control of various devices such as televisions, DVD players, and outlets. The ECU, pictured in Figure 10.7, allows the client, who has limited mobility and control of his arms, to operate these devices using two buttons that are pressed with his head.

The ECU operates devices wirelessly using infrared (IR) and radio frequency (RF) signals. Devices such as televisions and DVD players are operated using IR signals whereas RF signals control outlets. Individual IR remote control codes are programmed into the ECU by the user or a caregiver whereas RF signal codes are preprogrammed to interface with commercially available X10 modules that control outlets using existing household wiring for communication.

Programming IR remote codes into the ECU is required by a caretaker whereas RF signal codes are preprogrammed to interface with commercially available X10 modules that control outlets using existing household wiring for communication.

Fig. 10.7. Environmental Control Unit.

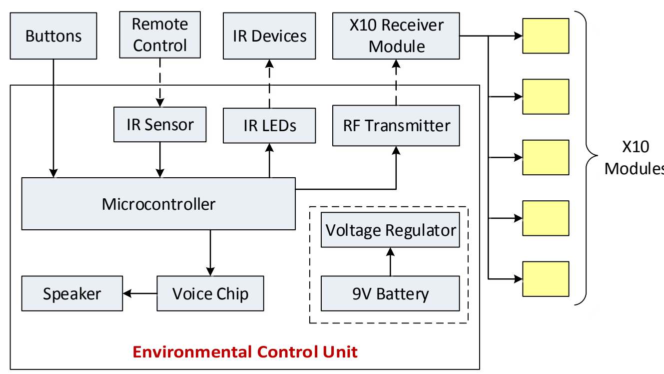

Fig. 10.8: Block Diagram.

SUMMARY OF IMPACT

The ECU allows a user to operate common household devices without the aid of another person. The programmability of the ECU gives users the flexibility to control a wide range of devices. The ECU's simple two-button operation and voice feedback make the device simple for the user to operate. Similar units exist on the market but the ECU's simple design, low cost, and ability to interface with other devices make it a desirable product.

TECHNICAL DESCRIPTION

As shown in Figure 10.8, the ECU consists of nine main components: 1) buttons, 2) voice chip, 3) speaker, 4) microcontroller, 5) infrared sensor, 6) infrared LEDs, 7) RF transmitter, 8) X10 modules, and 9) power supply. The device dimensions are a compact 6" x 3.5" x 2", which allows easy attachment to the client's wheelchair.

To operate the ECU, the client uses two buttons to navigate through main and submenus. The client first selects the desired device in the main menu and then selects the desired device function in the submenu. Each button is capable of two menu operations differentiated by single- or double-press. The menu layout and details of the button functions are shown in Figure 10.9.

To allow the client to navigate menus more easily, an ISD17240PY voice chip is used to play voice prompts which notify the current position within menu or submenus. The microcontroller operates the pins for ‘play’ and ‘forward’ on the voice chip to play the appropriate recordings. The voice chip provides adequate amplification to drive the connected eight ohm speaker.

To program IR remote codes, a caretaker presses the red program button on the ECU and points the remote directly at the IR sensor on the ECU. An LED is turned on to indicate that the ECU is, and will remain, in program mode until the program button is pressed again or an IR signal is detected. When a signal is detected, the microcontroller time stamps all of the signal’s rising and falling edges and places them into an array. Each IR device on the ECU’s menu is designated by its own array.

To transmit IR signals, a timer is initialized to zero and starts counting. The port on the microcontroller connected to the IR LEDs toggles whenever the timer is equivalent to the times in the array containing the rising and falling edges. Since IR wavelengths used among manufacturers vary, the ECU uses three IR LEDs of different wavelengths to transmit IR signals to ensure compatibility with most brands.

The ECU transmits RF signals at 310MHz using a TX-66 RF transmitter board by Ming Microsystems. An X10 receiver module plugged into an outlet receives the RF signal from the ECU and relays the signal through household wiring to other X10 modules plugged into other outlets. The X10 modules operate using on-off keying just like the IR LEDs.

The ECU’s power supply consists of a nine volt battery connected to an LM7805 voltage regulator which provides a five volt supply to the entire unit.

The cost for the environmental control unit without X10 modules is approximately $50. Each X10 module costs about $13 and can be purchased as needed.

Main Menu	**Sub-Menu**				
Television	Volume Down	Volume Up	Channel Up	Channel Down	Power
DVD Player	Play	Stop	FFW	REW	Power
Outlets	Device 1	Device 2	Device 3	Device 4	Device 5

	Main Menu		**Sub-Menu**	
	Single-Press	**Double-Press**	**Single-Press**	**Double-Press**
Button 1	Scroll down	Enter Sub-Menu	Scroll right	Activate device
Button 2	Scroll up	Do nothing	Scroll left	Back to Main Menu

Fig. 10.9. Menu Layout and Button Functions.

E-Z REMOTE

Designers: Feng Guo, Jacob Marshall, Thsering Angmo and Yichuan Zhao
Supervising Professor: Dr. Mark J. Schroeder
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Fargo, ND -58105

INTRODUCTION

The E-Z Remote is a device that can control multiple electronic devices such as TVs, DVRs, lamps, fans, and others. The remote is designed for Tyler who has cerebral palsy, but with slight modification to the user interface the E-Z Remote can accommodate persons with various physical disabilities. Users operate the E-Z Remote through a simple two-button interface and all functions are accompanied with an audio output. The E-Z Remote uses power line communication to provide on/off control of electrical devices. Further, the E-Z Remote can learn commands from standard infrared remote controls. Based on the client's request, the E-Z Remote also provides an integrated radio and a soothing acrylic display. The completed remote, including the two-button interface, is show in Figure 10.10.

This is the fourth device designed for Tyler. Earlier designs include: 1) HDC (home device controller), a device to control a home theater system with an easy user interface and an affordable cost, 2) Remote Control II, a remote designed as an application for Android devices with an added infrared interface, and 3) ECU (environmental control unit), a device that is similar to the E-Z Remote except that it lacks audio output, modified infrared interface, built-in radio, acrylic display, and DC power adapter. Beyond these designs, several commercial devices are available but they are generally expensive while the E-Z Remote is very affordable.

SUMMARY OF IMPACT

The E-Z Remote is a device specifically designed to accommodate the abilities and needs of Tyler, although it is also appropriate for persons with general physical disabilities. The E-Z Remote controls all electronic devices that are used by Tyler on a daily basis. With this remote, Tyler is more self-sufficient and experiences an increased sense of independence, all while reducing the workload of his caretakers. Tyler enjoys listening to music so there is a built-in radio for his entertainment. This product also helps Tyler to communicate effectively as the E-Z Remote has an audio output that allows him to express feelings like thirst, hunger, and discomfort. The enclosure is lightweight and small enough to fit under a wheelchair.

Fig. 10.10. E-Z Remote.

TECHNICAL DESCRIPTION

As shown in Figure 10.11, the E-Z Remote is comprised of: 1) a power supply, 2) a PIC 18F4620 microcontroller, 3) two input buttons, 4) an audio output, 5) RF (radio frequency) - X10 communication, 6) an IR (infrared) module, 7) a radio and, 8) an acrylic display. The E-Z Remote is enclosed in a 9" by 6.5" by 3" plastic box.

The E-Z Remote is powered by a DC wall adapter or a 9-volt battery. When the DC adapter is used, the battery supply is automatically shut off. Regulators ensure both power types deliver the 5-volt supply required by the microcontroller and the remaining components.

The PIC 18F4620 microcontroller is the heart of the E-Z Remote; it is programmed with a menu structure to take input from the buttons and generate the necessary control signals for the audio output, RF-X10 communication, IR module, radio, and acrylic display. Users access menu items through two input buttons that are connected to the E-Z Remote using 3.5 mm jacks. A single click on the right button advances to the next option and a single press on the left button returns to the previous option. A long press on the right button enters a sub-menu and a long press on the right button returns to the main menu. All these options are followed by a voice message, which is delivered using an ISD17120 voice chip with 120 seconds of audio capacity. The chip uses an SPI (serial peripheral interface) bus format where the microcontroller acts as the master and the voice chip acts as the slave. Audio feedback is preferred over a visual feedback to match the preferences and abilities of the client.

RF-X10 communication is used to provide on/off control of electrical devices attached to a power line. X10 is an international standard that uses power line communication for signaling and control of electronic devices. The RF transmitter in the E-Z Remote transmits commands to an X10 receiver plugged into a wall outlet. The X10 receiver relays these commands to the appropriate X10 modules via the power line. The E-Z Remote's TXM-315-LR RF transmitter chip operates up to 50 m, which gives the E-Z Remote a good range of operation.

The IR module is used to control IR-equipped devices. The E-Z Remote learns the IR commands of various devices via the IR module and saves the signals in EEPROM (electrically erasable programmable read-only memory). Signals are received and saved using a single button that is placed on the enclosure and is intended to be used by the installer or the caretaker. The IR module transmits these control signals to the respective devices following proper menu-item selection by the client.

The radio is interfaced with the microcontroller and the user can control power, reset, scan and volume using the E-Z Remote input buttons. A DS 1666-10 digital resistor is used to control the volume. The buttons can also control the power and pattern of the acrylic display. There are five patterns stored in the microcontroller for the display.

The cost of the E-Z Remote is approximately $165, including the buttons and X10 modules.

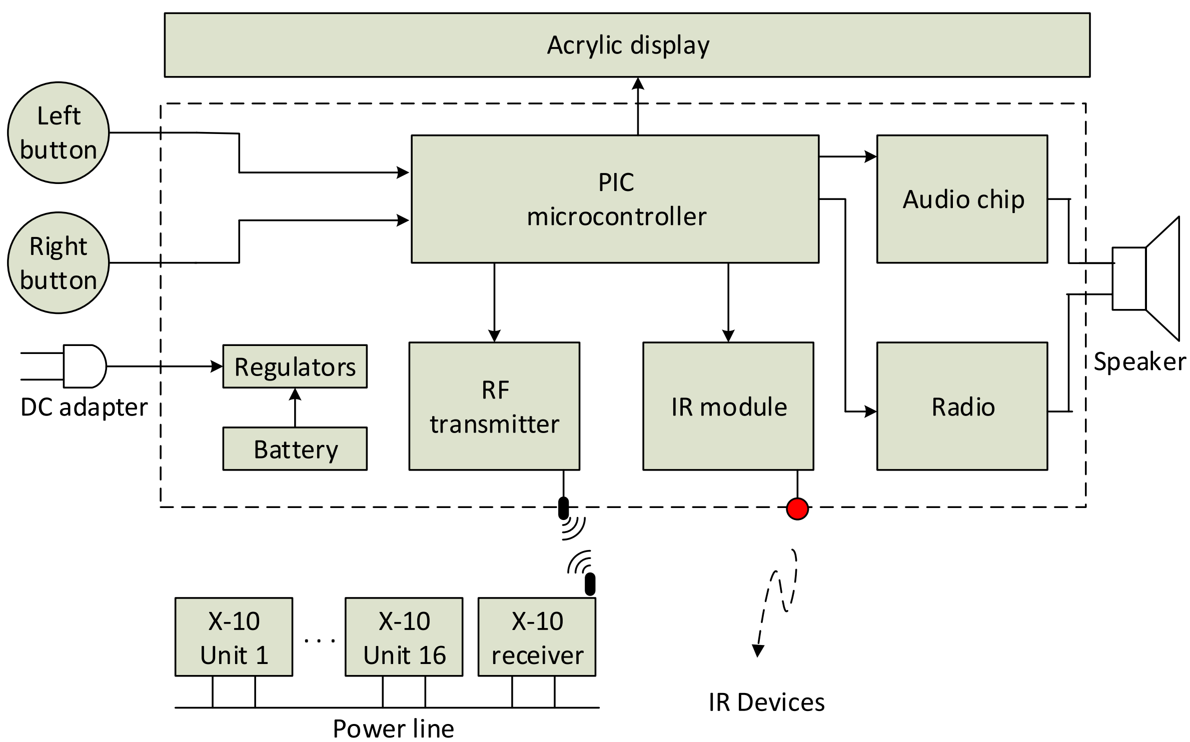

Fig. 10.11. E-Z Remote Block Diagram.

AMIABLE: A WEBSITE FOR PERSONS WITH DISABILITIES

Designers: Geetika Chaudhary, Kaylee Hofschild, Isha Kukreja, Alysia Stoffer
Supervising Professor: Dr. Mark Schroeder
Electrical and Computer Engineering Department
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Fargo, ND 58105

INTRODUCTION

Amiable is designed to provide a one stop shop for persons with disabilities and their caretakers or loved ones. The Amiable website contains products from the most popular companies that serve persons with disabilities. Figure 10.12 shows the home page of Amiable, which includes a search bar, search categories, welcome message, and other information. Until Amiable, people had to undergo a potentially time consuming and frustrating search of many different websites to locate relevant products for particular disabilities. Amiable alleviates these burdens.

SUMMARY OF IMPACT

The Amiable website gives the user, whether that is a person with a disability or their caretaker, the ability to successfully find the disability products they need without searching through multiple sites. With Amiable, people can find products for a certain disability with ease. Amiable also gives them the capability to submit a product request if there is a product they need that does not currently exist. These product requests are directed to North Dakota State University for consideration as future senior design projects. By combining the search functionality and the ability to request products, Amiable makes finding products for disabilities much easier.

TECHNICAL DESCRIPTION

The two main parts to Amiable are the database and the website. There are also several subparts, including: 1) recordset, 2) e-mail address, 3) PayPal, and 4) site analytics. A block diagram for Amiable is shown in Figure 10.13.

Amiable has a large database of products collected through product research. Classifying disabilities, finding companies that sell disability products, and compiling product information into excel spreadsheets are all part of product research. Disabilities are classified as either physical, mental, or developmental, which can be seen on the left hand side in Figure 10.12. The physical disability category is further categorized as hearing impairment, visual impairment, or mobility impairment. Currently, there are 1,025 products in the website for the 12 most common disabilities. Product information, gathered from popular companies that serve persons with disabilities, is compiled into excel spreadsheets. For each product, there are five items documented: 1) product name, 2) product hyperlink, 3) product keywords, 4) product description, and 5) product image location. The product name, hyperlink, description, and image are available for display to the user for each product listed.

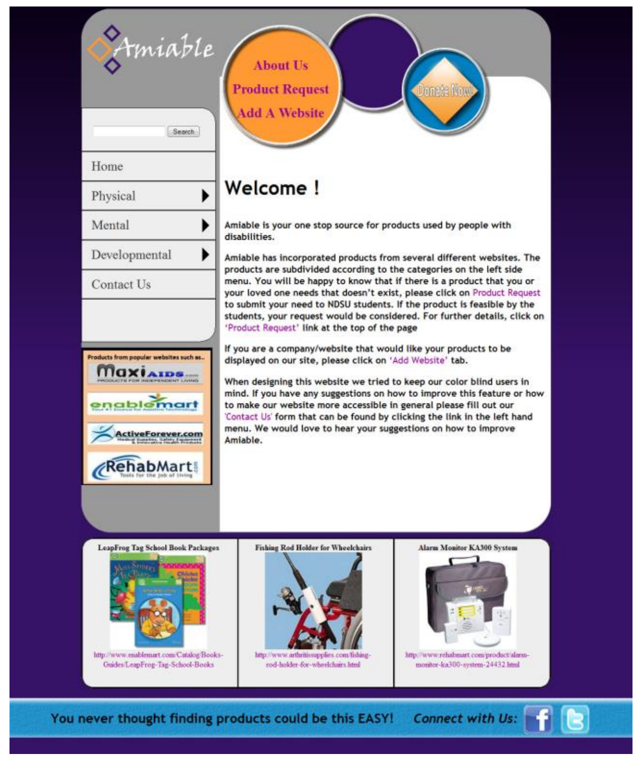

Fig. 10.12. Amiable Website Home Page.

The database is stored with a single table in MySQL, a database management system. The spreadsheets containing product information are uploaded into the database by Amiable designers. There are five fields of information in the database table, matching the five items compiled for each product. Each field is set up as a varchar, which stands for variable character. A varchar accepts both text and hyperlinks. The database is linked to the website, which is required in order to allow Amiable to search the database for products.

Amiable is built in Adobe Dreamweaver and uses four different coding languages: 1) HMTL, 2) PHP, 3) CSS, and 4) JavaScript. Each language is useful in different ways for the website. HTML is the foundation of the website, meaning most of the code for the site is done using HTML. PHP is used for the recordset and sending submitted forms to an e-mail address. CSS makes up the style of the website, such as the colors and fonts. JavaScript is used for form validation and linking to site analytics.

In Adobe Dreamweaver, a database is searched using a recordset. The recordset accepts a search parameter entered by the user, such as "wheelchair". The search parameter is compared to product keywords listed in the database. After the search is complete, matching results are sent back to the website from the database, which is done through the recordset. The key subpart linking the database and website is the recordset, which is shown in Figure 10.13.

The e-mail address for Amiable is set up to accept all submitted forms on the website through PHP code. There are three forms on Amiable: 1) product request, 2) add a website, and 3) contact us. When any of these forms are filled out and submitted, the information filled out is sent to the Amiable e-mail address. The e-mail contains all the information the user fills out in the form. Each form is validated, meaning the user must fill out correct information for each field. For example, when a user is filling out the e-mail field, there must be an "@" symbol entered.

Site analytics, including Google and Go Daddy analytics, are useful tools for Amiable. Whenever someone is on the website, information on what that person is doing is recorded using site analytics, which keep track of how many people search the website and from what locations. Site analytics also keep track of the pages each person visits. The results gathered from the analytics can be used to better advertise the website. This information is stored on a separate webpage only visible to website managers.

Amiable is a nonprofit organization but it still needs funds to stay running. The website is funded by donations, which are done through PayPal, an online, secure method to transfer money. There is a button on the site for people who wish to donate. When the "Donate" button is clicked, the page goes from Amiable to PayPal. The user selects an amount to donate, fills out the credit card and personal information, and the money is sent to an Amiable account.

The initial cost for Amiable is $80, which includes hosting and a domain name for one year. Amiable's hosting package includes $50 to use towards Google Ad-words, which places advertisements for Amiable on Google searches, and $50 towards Facebook and Twitter advertising. Using social media, such as Facebook and Twitter, allows news and updates from Amiable to be available to the general public.

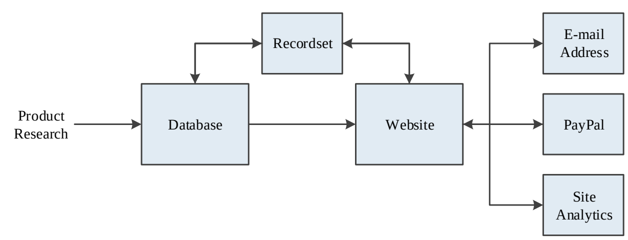

Fig. 10.13. Block Diagram of Amiable.

CHAPTER 11
NORTH DAKOTA STATE UNIVERSITY
(ME Dept.)

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AN UPRIGHT STANDING ELECTRIC WHEELCHAIR

Designers: Bevan Bredson, Tryg Bredson, Jason Hemmer and Ryan Whitcre
Client Coordinator: Bethany Homes for Independent and Assisted Living, Fargo ND
Supervising Professor: Dr. Majura F. Selekwa
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Fargo, ND, 58105

INTRODUCTION

An upright standing wheelchair was designed to provide mobility for people who have been temporarily disabled, probably due to some accident, and during their recovery process they become wheelchair bound. The wheelchair has three critical mechanisms for safely holding in place and lifting the user into an upright standing position as illustrated in Figures 11.1 and 11.2. The mechanical design of the wheelchair was completed and tested but, unfortunately, the electronic control system burned out in the last stages of the project, and the designers graduated. As such, the wheel hair was not presented to Bethany Homes, as it awaits the redesign of the control system and subsequent testing. A separate design project will be carried out next year for designing all electrical control systems for this and similar projects under the program.

SUMMARY OF ANTICIPATED IMPACTS

This project was for assisting people who have been temporarily disabled by traumatic events, such as road accidents causing them to lose their ability to walk. In their recovery process, these patients must undergo some form of physiotherapy; the most basic being standing up. As part of physiotherapy services, each therapist at Bethany Homes is limited to assisting only one patient with standing exercises at a time. This can be time consuming if the number of patients is more than the available therapists. An upright standing wheelchair was seen as the immediate tool that can help provide patients with the ability to perform independent body stretching exercises by being able to stand upright without the aid of a physiotherapist. The development of this wheelchair will make it possible for the facility to offer physiotherapy services to many patients using fewer physiotherapists.

Fig. 11.1. The Sitting Position Concept and the Final Product.

Fig. 11.2. The Standing Position Concept and the Final Product.

TECHNICAL DESCRIPTION

This wheel chair has two high powered servomotors for holding the user in a safe position, two linear actuators for lifting the user to an upright position and two brushless hub motors (BLDC) for moving the wheelchair from one position to another. In addition to these actuators, the wheelchair is equipped with one 16-bit Arduino microcontroller and one three-axis accelerometer for monitoring and controlling the wheel chair position to maintain safe conditions for the user. As expected, all power drivers for these actuators are part of the system. Finally, the wheelchair has one six-axis joystick that the user will use to operate the wheelchair under the supervision of the microcontroller.

The two DC motor driven linear actuators are for lifting the user to an uptight position. The actuators are securely mounted at a fixed position where they are free to rotate; they extend to push the chair up to a standing position, and they retract to pull the chair to a sitting position. Initially, the design was to use bang-bang ON-OFF controllers for these actuators, but preliminary experiences with the wheelchair under the bang-bang control conditions necessitated the change to pre-programmed speed profiles using H-Bridge drivers and a microcontroller. Unfortunately, transitioning to preprogrammed speed control profiles turned out to be too much for mechanical engineering student engineers working on the project as they were not prepared for this level of complexity.

The user is held in place when the wheelchair transitions from sitting position to standing position by using two servomotors that operate the restraint mechanisms. These servomotors can be calibrated to the size of the user before engaging them. Constant speed, single transistor driver circuits were designed to handle the power requirements of these servomotors. The control system for these servo motors works well as intended.

The BLDC motors that drive the wheels were to be driven by using off-the shelf BLDC motor drivers that were recommended for these motors, all linked to the joystick and the microcontroller for coordinating the wishes of the user and the dynamics of the actuators on that wheelchair. Toward the end of the project, the student engineers realized that the BLDC motor drivers that were recommended had a short tolerance range and failed easily after a momentary overload as shown in Figure 11.3. Since the student engineers were graduating, the project was left in that condition until the next group takes over the project. The next group will be required to be a mix of both electrical engineering and mechanical engineering students for the project to succeed.

The overall cost of parts and materials for this project was $ 2,520.

Fig. 11.3. The Failed Brushless Motor Drivers.

CHAPTER 12
THE PENNSYLVANIA STATE UNIVERSITY

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ADAPTIVE CYCLE FOR A LIMBLESS INDIVIDUAL

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Client Coordinator: Chris and Gretchen Kaag
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Supervising Professor: Dr. Margaret Slattery
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206 Hallowell Building
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INTRODUCTION

The goal of this project was to design a cycle for Craig Dietz, who was born without fully developed limbs. Craig, already an avid swimmer, wants to be able to bike in order to participate in duathalons. Sponsored by the IM ABLE Foundation, the bike needed to be easy to use, yet safe and durable. This was the second iteration of the cycle, which was started spring semester 2011. Steering, pedaling, and shifting were the features of the cycle that required the most modification from last year's design. A usable pedaling mechanism was the main focus of this year's efforts. Secondary concerns included improving the comfort of the cycle and making it easier for Craig to mount the cycle unassisted.

The team came up with multiple pedaling design concepts after reading last year's report, conducting background research, and meeting with Craig and our sponsors. All of these concepts involved limiting Craig's motion relative to the vertical axis. A ratcheting pedaling mechanism was deemed the best solution to the problem and a prototype was constructed based on this design. Figure 12.1 shows Craig testing the prototype cycle.

SUMMARY OF IMPACT

Now that the cycle is built, Craig is able to stay active while maintaining his independence. Craig believed we took a step in the right direction with the pedaling mechanism as the design is functional. However, due to the short distance covered with each push of the pedal it would be impractical to use it during a race such as a duathalon. Major refinement of the pedaling mechanism will be needed. Craig highly rated the shifting mechanism, which was a new addition to the cycle this year. Minor adjustments were made to the braking mechanism in terms of position and sensitivity of the brakes. The steering

Fig.12.1. Mr. Dietz Tests the Prototype Cycle.

mechanism requires only minor refinements in future designs, such as the addition of a fin to improve steering ability and adjusting the angle of the steering cup.

TECHNICAL DESCRIPTION

The team had initially chosen a four-bar linkage as the recommended design because it best met the customer needs. However, after initial prototyping, it was determined that it would be difficult for Craig to make a full rotation of the bike's crank. To overcome this problem, the four-bar linkage was modified into a spring-assisted ratcheting mechanism (Figure 12.2). This ratcheting motion made shifting on an external derailleur nearly impossible, so an internally shifting hub was purchased. Internal hubs can shift gears without requiring any motion of the pedal crank.

Testing was conducted to evaluate the efficacy of the various bike mechanisms. It was shown that Craig could travel an average speed of one foot per second. The bike was able to come to a complete stop in an average of 107 inches after traveling 10 miles per hour. Right and left turning radii were measured at 68 and 50 inches respectively. Craig qualitatively rated each of the bike's mechanisms from 1 to 5, with 5 being the highest rating. Overall, all of the mechanisms and ergonomics of the cycle were rated highly at 4 out of 5. The only exception was the pedaling mechanism, which was rated at 2.5 out of 5. This was a significant improvement over last year's 1.5 rating of the pedaling mechanism because Craig was able to pedal the bike on his own. Our main recommendation for next year is to use a larger front sprocket to increase the pedaling gear ratio or to develop a new mechanism capable of making a full rotation of the bike's crank.

The cost of materials to build the cycle, including the internal hub, came to a total of $557.70. When travel and other expenses were included, the tem spent a total of $969.23 out of the allotted $1000 budget. Including the money spent on last year's materials, it would cost $1258.57 to build an identical cycle. Final deliverables for the project included a completed cycle, a SolidWorks model of the cycle's components, documentation of the design process, and a final report.

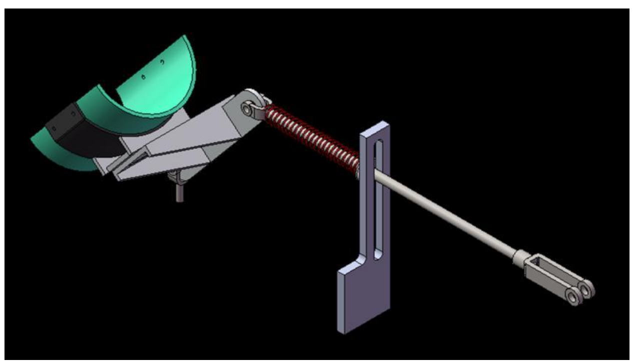

Fig. 12.2. Solidworks Rendering of the Ratcheting Pedaling Mechanism.

ADAPTIVE SAILBOAT SEAT

Designers: David Cardona, Navdeep Hanspal, Troy Kelley, Rachel Lee, Bill Wolf
Client Coordinator: Richard Allwein
PA Spinal Cord Injury Support Group
Hershey, PA
Supervising Professor: Dr. Mary Frecker
Department of Mechanical and Nuclear Engineering
The Pennsylvania State University
University Park, PA 16802

INTRODUCTION

Today more than ever paraplegics have opportunities all over the world to sail. Special harnesses and sailboats have been designed to accommodate for individuals confined to wheelchairs. However, many times these individuals have to sail with the help of other individuals on board and resources required to sail independently can be scarce. Additionally, there are currently no sailboats that cater to individuals who prefer to use a prone cart. A prone cart is a wheel chair that is designed to support an individual who is in a prone position, lying on face down on his or her stomach.

Richard Allwein is a paraplegic who prefers to use a prone cart. A prone cart is a wheelchair that is operated from the prone position, on one's stomach. Mr. Allwein is not able to move his legs; however, he has full and complete functionality off his arms which allows him to perform many tasks independently. Mr. Allwein prefers to use a prone cart because sitting in traditional wheelchairs causes pressure sores and back pain. The prone cart is much more comfortable for Mr. Allwein and he is better able to maneuver and operate while using a prone cart.

The goal of the project was to design a sailboat seat that caters to prone cart users; the resulting prototype is shown in Figure 12.3. The seat should elevate, descend, and rotate in a manner that counters motions produced by waves while sailing. While elevated, the user will be in an inclined position at an angle at which operating a steering wheel is comfortable. Mr. Allwein also specified that he wanted to be above the steering wheel while elevated so that steering feels more natural. A designated area of the boat was selected, measured, and dimensioned for the placement of the seat and apparatus. Also, another one of Mr. Allwein's prone boards that is used to operate a riding lawn mower was dimensioned and its elevating and descending mechanisms were observed. While the seat is in a lowered position, Mr. Allwein plans to maneuver around the sailboat under his own strength.

Fig. 12.3. Photo of Adaptive Sailboat Seat Prototype.

SUMMARY OF IMPACT

Globally, there are few products made for paraplegics who prefer to operate devices from the prone position. The project sponsor designs and constructs devices that enable him to operate different types of machinery and shares his designs with other paraplegics around the country. The current market for prone position devices is small and could be considered absent with regard to sailing equipment. The prototype developed by the group will not only be seen by just the sponsor, but multiple paraplegics in a variety of locations. With so many individuals getting a chance to see the prototype and how it was constructed, revisions can be made so that the seat can be made so that the seat can eventually be implemented onto the boat. Additionally, other seats with different dimensions and functions can be constructed to fit different boats, users, and sailing situations. The adaptive sailing seat needed to satisfy two basic needs. It must be able to adjust into two distinct positions, one collapsed and one upright so that the sailor may steer.

TECHNICAL DESCRIPTION

The lifting mechanism is guided by a two position motion generated system whose path is determined by a four-bar linkage. The four bar linkage provides to positions in which the seat can be locked in, a collapsed position and the elevated position. The collapsed position allows the user to mount the seat and the elevated position is used when operating the boat. The lifting legs are driven by gas powered springs that can lock when in the extended position, to overcome an unforeseen collapse of the seat.

In order to allow the sailor to react to keeling, a central spine used to allow the sailor to roll left and right to balance him as the boat keels. To keep the sailor locked in a preferred position, a sprocket/lever system was used. The sprocket remained stationary along the shaft, while the lever was attached to the prone frame so that they move independently of each other. If the sailor wants to adjust his position, he simply pushes down on the lever and release it when he is comfortable. Once the lever is released, the tension in the spring will lock the lever into the sprocket.

ASSISTIVE LUNCH TRAY DEVICE

Designers: Bryan Ooi, Marissa Webb, Niya Robinson, Daniel Harajda, Ryan Plessinger
Client Coordinator: Rhonda Aveni
Curwensville School District
Curwensville, PA
Supervising Professor: Jason Moore, Ph.D.
Department of Mechanical and Nuclear Engineering
The Pennsylvania State University
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INTRODUCTION

Lydia Swatsworth was born without arms, but has overcome her difficulties using her feet and fused appendages. One obstacle she has yet to conquer is holding her lunch tray without assistance. This project required designing and constructing a lunch tray carrying device for her. After meeting with Lydia, her mother, physical therapist, school special education teacher, and two of her care aids that help her daily during school, the team learned that the device has to be lightweight, portable, durable, and easy to clean and fit trays of different sizes. Also the team was asked to build two of the same product. Research on existing products and patented designs currently on the market revealed that all of the products were either too heavy to be carried by a 7 year old, not portable or required arms to use. The final design of the prototype is displayed in Figure 12.4.

SUMMARY OF IMPACT

With the team's design, Lydia is able to carry the tray independently without the aid of her care team. Currently the device is slightly heavy for Lydia (1.2kg/ 2.65lb) but the team believes that as she builds strength, this will no longer be a hindering factor. The following is a statement made by our supervisor, Rhonda Aveni: "This device is well designed and will allow Lydia to be more independent."

TECHNICAL DESCRIPTION

The team's final design was made of carbon fiber/Kevlar because it is 25% lighter than aluminum

Fig. 12.4. Photo of the Prototype Lunch Tray.

and more durable than pure carbon fiber. A drawing of the design is shown in Figure 12.5. The side of the tray, in contact with Lydia's stomach, is curved and padded to add both comfort and stability. The nylon straps used were sewn into a "Y" shape, and were completely adjustable at all 4 ends. In addition, an FDA compliant silicon rubber sheet was adhered to the carbon fiber/Kevlar base as a non-slip surface. Lastly, friction resistant aluminum hinges were added down the centerline to prevent the tray from collapsing in either direction and for the tray to be folded in half for portability purposes. Overall, the device met the customer needs of being durable, adjustable, under $1000, and hands free. The cost of manufacturing one tray is approximately 370 dollars.

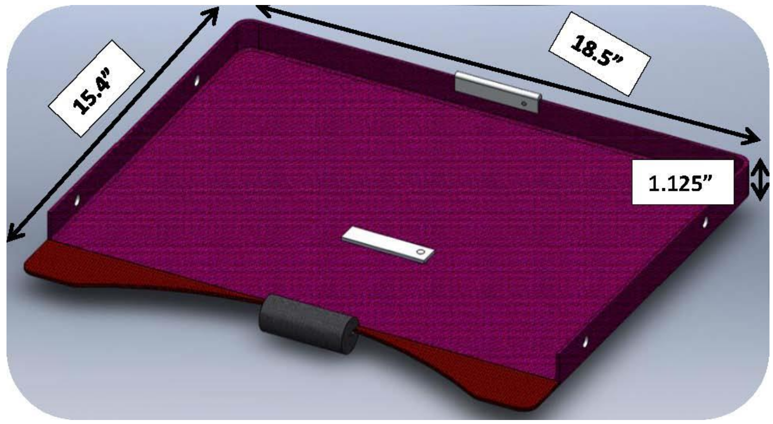

Fig. 12.5. Isometric View of the Lunch Tray without the Nylon Straps.

ASSISTIVE TOILETING DEVICE

Designers: Monica A. Byrne, Ling Hui Chang, Emily A. Foster, Lauren M. Harter, Katherine L. Johnson
Client Coordinator: Rhonda Aveni
Curwensville School District
Curwensville, PA
Supervising Professor: Margaret Slattery, Ph.D.
The Pennsylvania State University
Department of Bioengineering
University Park, 16802 PA

INTRODUCTION

Lydia Swatsworth is a young girl who was born without arms and instead has two fused finger-like appendages. While she has learned to do many daily activities using either her finger-like appendages or her feet, she still requires assistance from a personal care aide when using the restroom. The goal of our project was to design a device that will allow Lydia to use the bathroom independently at home and at school. Lydia's care team hoped that the final device could be easily sanitized and transported and could grow with her. They also laid down several needs, which would later serve as the major guidelines during the design and construction of the prototypes. The eight focused customer needs, ranked in terms of importance are safety, sanitation, ease of use, adjustability, comfort, price, portability, and durability.

An external search was conducted to find patents and products of existing assistive toileting devices in the market. While no current device met the specific design criteria and customer needs, there were few designed to extend a person's reach for those with limited manual dexterity. All of these designs required the user to attach the wipes manually to the gripping mechanism, a task which Lydia is unable to perform. Therefore, the existing designs are not applicable for Lydia. Images of the prototype device are shown in Figures 12.6 and 12.7.

Fig. 12.6. A) Prototype of Device to be used from the front. B) Wipe Loading Stand Prototype.

SUMMARY OF IMPACT

Our device has opened many doors for Lydia. With our device, Lydia is able to gain the independence in the restroom that she and her care team desired. Currently Lydia still requires assistance from a care aide to use our device. However, we are confident that with practice, Lydia will soon be able to use our device entirely on her own in the bathroom, without any help from a care aide or her mother. Also, Lydia's care team has been brainstorming on how to make adaptations using components of our design to create other devices that will enable Lydia to perform more daily tasks independently.

The following is a statement made by our supervisor, Rhonda Aveni, expressing her feelings about our final device design and deliverables: "Excellent design. Will be an excellent tool for Lydia's independence. Thank you!"

TECHNICAL DESCRIPTION

The assistive toileting device is a purely mechanical device that has the entire wipe attachment mechanism located at the bottom of the device. The claw-closing mechanism (Figure 12.7A label E) consists of a pair of claws shaped from spring stainless steel that are screwed to a mobile piece fabricated from Delrin. Most of the parts were fabricated by cutting ½ inch CPVC pipes to size and connecting those using CPVC fittings, including a 45^{o} connector and tee connectors. The shoulder loop (Figure 12.7A label C) is made out of fiber reinforced tubing and CPVC pipe. The wipe loading stand consists of a Plexiglas insert that is housed in a plastic pencil box, as shown in Figure 12.6.

Two separate devices were created to allow Lydia to wipe both in the front and the back. The back device incorporates an elongated C-shaped curve as the middle piece (Figure 12.7A label D) connecting the shoulder loop and the claw-closing mechanism. This curved shape was achieved by bending the CPVC pipe after heating it with a heat gun. A separate set of adjustable devices were also created, for both the front and back devices, which Lydia will use once she outgrows the current devices. The middle pieces (Figure 12.7A label D) of the adjustable devices are composed to CPVC female adapters and removable threaded CPVC pieces that can be exchanged to add length to the device. These threaded pieces, shown in Figure 2B, come in small, medium, large, and extra-large lengths. Larger shoulder loops were also created to accommodate Lydia's growth.

The device is very easy to use, as it requires only a downward force to activate the claw attachment mechanism. When Lydia inserts the tip of the device into the hole of the wipe loading container, the claw-closing mechanism is engaged, forcing the claws to shut down over the wipe. The mechanism can be disengaged by catching the release rod onto the inner lip of the toilet seat, which then releases the wipe into the toilet. Analysis showed that 2 lb.-in of work is required to disengage the locking mechanism, a value that is easily achievable by Lydia. Finally, as the various devices are composed of relatively inexpensive materials, the total cost to reproduce a single device is $27.80.

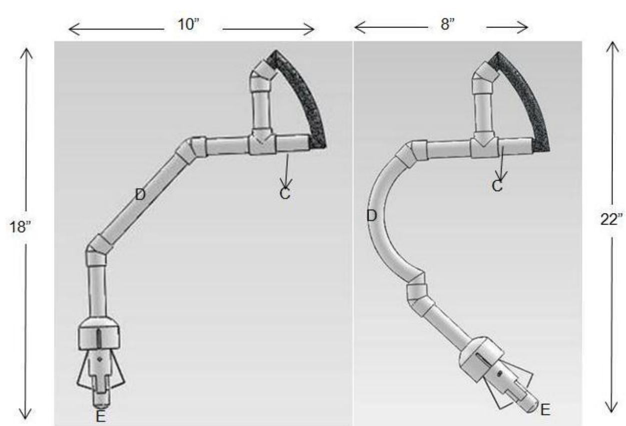

Fig. 12.7. A) View of Front and Back Devices. B) Different Sizes Connecting Pieces.

BIONIC GLOVE: C-6 TETRAPLEGIC LIFTING GLOVE

Designers: Daniel Collins, Greg Henderson, Evan Hendrick, Chris Lawson, and Chris Martinez
Client Coordinator: Dr. Everett Hills and Keith Parsons
Penn State College of Medicine
Hershey, PA
Supervising Professor: Dr. Mary Frecker
Department of Mechanical and Nuclear Engineering
The Pennsylvania State University
University Park, PA 16802

INTRODUCTION

The purpose of this project was to design a bionic glove for people who cannot grip items but can move their wrist and arm. This will allow them to lift weights without the aid of others. Currently, there exists on the market a specialized leather glove to assist in gripping around a barbell, but the user must be assisted by someone to strap the weight to their hand. This bionic glove shown in Figure 12.8 solves this problem by closing and opening their hands automatically. This allows the user to become more independent as an individual and be more efficient in daily activities.

SUMMARY OF IMPACT

The sponsor, Keith Parsons, lost the function of his legs and suffered nerve loss throughout many of his extremities due to a spinal cord injury accident. Without the use of his legs, Keith relies mainly on his upper body to provide the forward force needed to move himself and his wheelchair. This amount of physical exertion on his body can fatigue him. To remedy this, he exercises to build and maintain the muscles of his arms and shoulders. He can move his arms and wrists for various exercises, but due to his disability, he is unable to grip objects such as a barbell on his own. The Bionic Glove allows him to grip weight bars so he can lift weights independently.

TECHNICAL DESCRIPTION

The Bionic Glove is shown in Figure 12.8. It provides the necessary assistance to help the hand of the user to grip around a bar for weight-lifting purposes. It incorporated design features such as the ratcheting system (A), the pawl-release system (B), Five-Bar Linkage (C), LED Timer (D), Velcro Wrist Straps (E), and a Servo Motor (F).

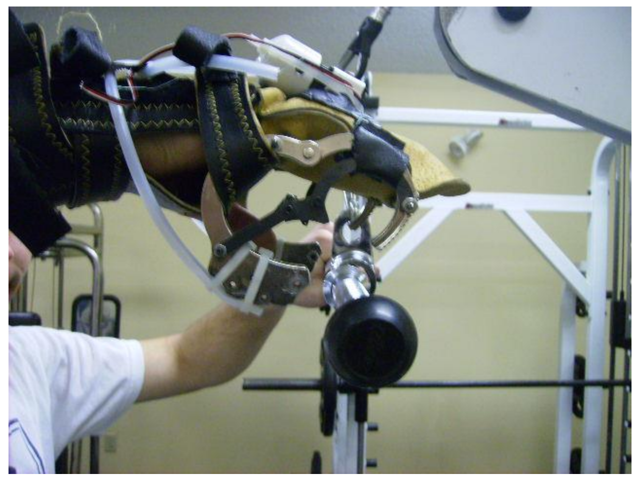

Fig. 12.8. The Bionic Glove Prototype.

The device works as a staged process. First, the user slides his/her hand into the glove and uses their other hand or other means to tighten the Velcro wrist straps (E) onto their wrist. Next, the user pushes the LED Timer Buttons (D) located on the side of both gloves for the desired amount of time before the servo will engage and reopen the handcuffs. The diagram of the circuit for the LED timer is shown in Figure 12.9. Next, the user approaches the weighted bar they intend to pick up. The user then slides their hand underneath as if to grab the bar and pushes the weighted bar against the joining bar of the five-bar linkage (C). As the user begins to lift the weighed bar, the weight of the bar will further close the handcuff due to the five-bar linkage system. Because of this, the mechanical lock/ratcheting system (A) will start to slide into the pawl-release system (B). The pawl that is within the pawl-release system will be the mechanical lock that holds the glove in a closed position.

Once the user is finished with the particular workout they were doing and the LED timer indicates time is almost up, they may release the weighted bar. Once the time is up, the microcontroller will send a signal to the servo motor (F) to turn on and begin to rotate. This rotation will start pulling in the slack of the wire (white line in Figure 12.9). This slack is introduced to allow the user to maneuver their wrist while lifting. Once all the slack is taken up, the servo will finish by pulling on the wire attached to the pawl. This will cause the pawl to pull away from the ratchet and allow the glove to be un-mechanically locked. The user then pulls their hands away from the weighted bar and can then proceed to their next task.

The parts that make up the final prototype cost approximately $160 but multiple prototypes were made for demonstration to the sponsor, so the total cost of the project was approximately $700.

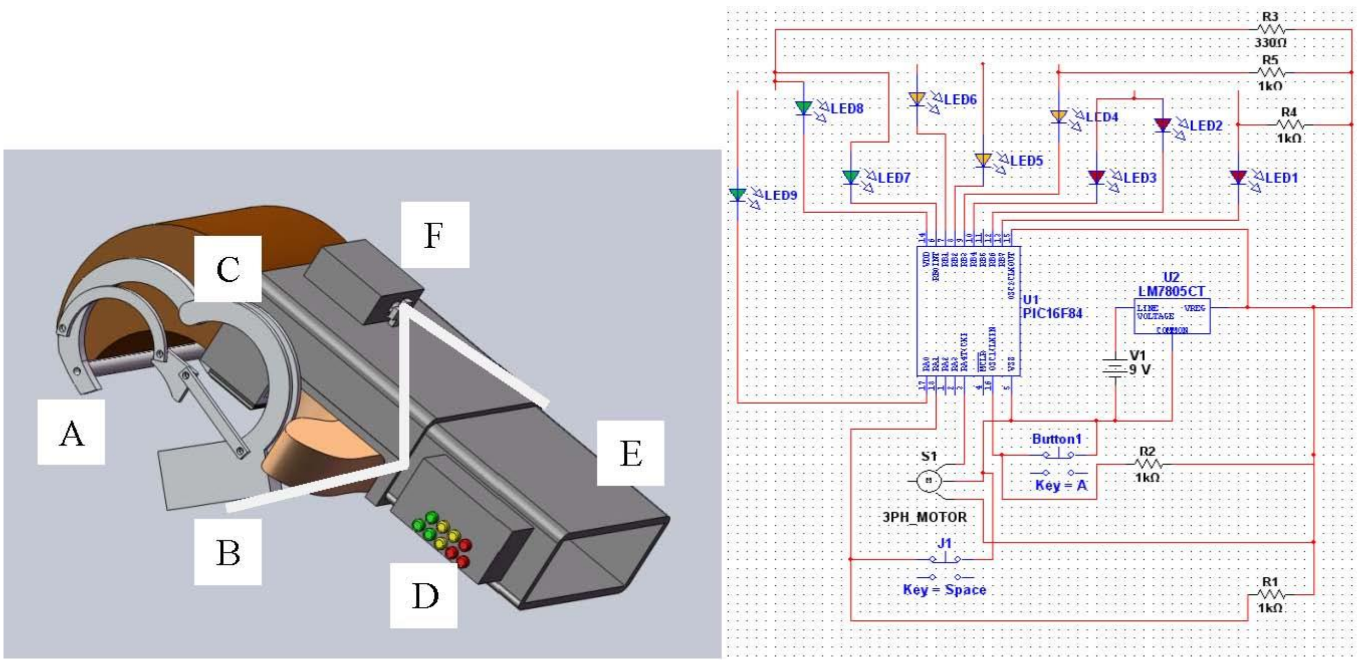

Fig. 12.9. A) Mechanical CAD of Bionic Glove B). Circuit Diagram of LED Timer.

PRONE HAND CYCLE FOR A PARAPLEGIC

Designers: Liz Campo, Steven Dickson, Rich Lukas, Tim Sayler, and Ramona Stanley
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Supervising Professor: Dr. Mary Frecker
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INTRODUCTION

The purpose of this project is to combine various functions of a prone hand cycle (pedaling, steering, and braking) into one multi-functional interface for a paraplegic. The client, Mr. Rick Allwein of the Central Pennsylvania Spinal Cord Injury Support Group, is a T12-L1 paraplegic. Additionally, Mr. Allwein has a history of pressure sores, and therefore cannot sit or kneel for extended periods of time. To better accommodate his needs, the hand cycle must support the user in the prone position, which involves lying on one's chest with legs fully extended. To ensure safety and control, Mr. Allwein expressed the need for an all-in-one steering, pedaling, and braking interface. The intended use of the hand cycle is for off-road recreation and exercise so the design must be suitable for rough terrain. Our hand cycle prototype is shown in Figure 12.10.

There are several hand cycles that are available commercially; however, the One-Off Hand cycle was the closest match to Mr. Allwein's needs. Though the One-Off Hand cycle employs hand pedaling as the driving motion, it does not accommodate the prone position because the user is required to kneel. In addition, this cycle utilizes chest steering and separate pedaling and braking interfaces, which Mr. Allwein deemed undesirable. It is difficult for the client to find a human-powered vehicle that fits his specific needs for a multi-functional handle unit and prone position support; therefore, a hand cycle needed to be custom-designed.

SUMMARY OF IMPACT

This design has the potential to help paraplegics everywhere get more exercise while enjoying fresh air. Since no other product fitting Mr. Allwein's needs currently exist, this project fills a gap for both him and others with similar conditions and provides an innovative means of recreation, exercise and

Fig. 12.10. Prone Hand Cycle Prototype.

mobility. Even those who do not usually lie in the prone position can use Team Trike's hand cycle to get outdoors and take a break from conventional wheelchairs and utilize different muscle groups that those used in a traditional wheelchair.

Mr. Allwein networks with paraplegics worldwide through blogging and his website, www.pronecartcity.com. Early in the design phase, he emphasized the need to create an economical design so that others can recreate the hand cycle on a budget. Mr. Allwein intends to share the prone hand cycle plans on his website so that others can benefit from the design and perhaps build their own prone hand cycle. It can easily be made for even less money by using more salvaged parts and less expensive material.

All of the customer's needs were met in the prone hand cycle that utilized an all-in-one user interface. The hand cycle design incorporated a strong frame and drive system that would be applicable to any future design aspirations that Mr. Allwein may have. Further design adjustments are needed to ensure a more accurate steering response; however, a solid foundation has been created that will allows our customer to have a fully functional and easy to use final product that was designed and fabricated in four months. The prototype design was also very economical in comparison to other products of its type on the market, costing approximately $810 without including shipping costs of materials – about 15% of the cost of the closest comparable product, the One-Off hand cycle.

When presented with the final prototype, Mr. Allwein carefully inspected the hand cycle, expressing satisfaction in the frame and platform stability. He further noted that he will be able to get much use out of the prone hand cycle.

TECHNICAL DESCRIPTION

The triangular frame, made from chro-moly steel, ensures stability by allowing for a three wheel design and accommodating the prone position. The cutaway shoulders allow for a greater range of motion and are similar to a design that Mr. Allwein has used previously. This frame supports a wooden platform with foam padding and risers to secure the user's legs. The platform is covered with a durable, moisture-wicking fabric. The rider propels the hand cycle by pumping the elliptical-style arms. The hand cycle is driven by a chain which connects to the back wheel. Long handles were selected to allow the rider to power the hand cycle using an elliptical motion and to ensure the cables from the handle levers did not tangle. These levers provide the inputs for braking, shifting and steering. When the shifting lever is activated, the tension in the steering cables rotates the steering plate, which then translates that motion to the tie rods, which turn the wheels. The pad angle, handle position on the flywheel, and handlebar length are all easily modified, allowing a great amount of user adjustability. Figures 12.11 and 12.12 show the hand cycle and

Fig. 12.11. CAD Model of the Prone Hand Cycle.

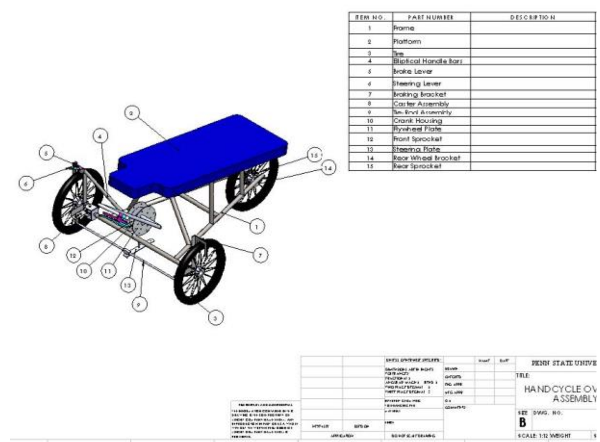

Fig. 12.12. Prone Hand Cycle Assembly.

PHYSICAL THERAPY iPAD APP

Designers: Megan Jurewicz, Ravi Shah, Rohan Shah, David Visco
Client Coordinator: John Wawrzyniak
Penn State College of Medicine
Department of Physical Therapy
Supervising Professor: Maggie Slattery, Ph.D.
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INTRODUCTION

Patients with a variety of sensory and motor disabilities often have physical therapy to help them maintain or improve their sensory and motor skills. Physical therapists will work with these patients in the clinic and teach them how to perform their rehabilitation exercises properly. The therapists will then prescribe the patients a set of exercises to perform routinely at home. They are given a sheet of paper with cartoon drawings of the exercise and a text description of how it should be performed.

These "at-home exercises" are an integral component of the patients' progress. However, if the patient performs his or her exercises improperly, it will set back the patient's rehabilitation. Performing exercises improperly may even hurt the patient instead of helping. Currently, patients must rely solely on the exercise sheet to remember how to perform their exercises. Unfortunately, the generic drawings often confuse patients, and as a result, patients may fail to comply with the exercises as prescribed.

This project focused on the development of a new method to prescribe exercises to physical therapy patients. The team created "PT @ Home," an iPad app (interface is shown in Figure 12.13) that uses custom videos to more clearly demonstrate the proper exercise and in theory improve patient compliance with their at-home exercise programs. PT @ Home allows physical therapists to record videos of their patient doing his or her own exercises. The therapist can then send those videos, along with other necessary information, to the patient via the internet. The patient can view those videos anywhere with internet access and perform his or her exercise regimen properly, keeping his or her physical therapy on track.

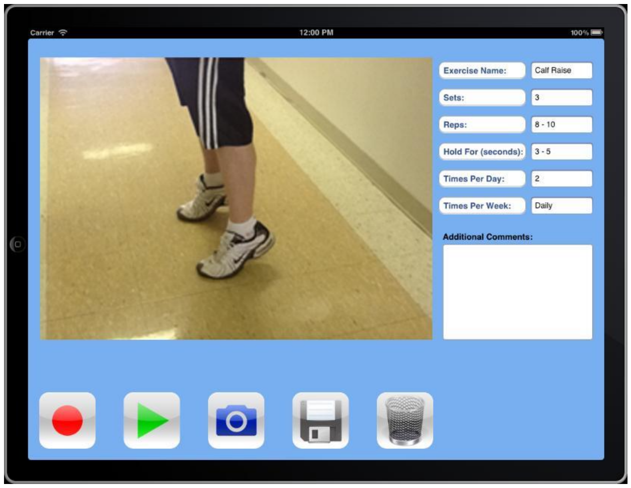

Fig. 12.13. User interface of the iPad App.

SUMMARY OF IMPACT

The PT @ Home iPad app is a unique product that allows physical therapists to maximize therapist-patient interaction. Instead of cutting back therapy time to construct the patient's at-home regimen, the app enables the therapist to create and customize the patient's exercise regimen while simultaneously providing therapy to the patient. This is possible because the therapist can record the video of the patient while the patient is in the clinic and undergoing his or her normal therapy.

The app is especially applicable to patients with disabilities. Patients with disabilities often require physical therapy to maintain or improve their sensory and motor skills, and the PT @ Home iPad app can help these patients perform their exercises properly. In May 2012, the PT @ Home app will be used in a clinical study to measure the effectiveness of video regimens in helping patients comply with their prescribed exercises. The medical professionals at Hershey Medical Center working with the project believe that the app will help physical therapy patients remember their exercises and therefore increase their capacity to stay on track with their rehabilitation schedule. In addition to helping patients make positive progress in their therapy, the video regimen may also decrease the likelihood that the patients will hurt themselves due to improper execution of the exercise.

TECHNICAL DESCRIPTION

The PT @ Home app is a single-view app. The six buttons along the right side of the screen are labeled "Exercise Name," "Sets," "Reps," "Hold For," "Times per Day," and "Times Per Week." Upon pressing "Exercise Name," a drill down menu drops down below the button. The drill down menu contains a list of ten anatomical joints. Selecting a joint allows the user to drill down to the list of exercises in that joint. Selecting the name of an exercise enters that text in the text field immediately to the right of the "Exercise Name" button. Pressing any of the other five buttons drops down a list of common values for that category. Selecting any of the values enters the value into the corresponding text field.

The user also has the option of typing into the text fields directly. Touching the text fields brings up a keyboard, and touching anywhere on the screen dismisses the keyboard. The "Exercise Name" and "Additional Comments" text fields bring up a full QWERTY keyboard, while the other text fields, which correspond to numerical information, bring up a number keypad.

Along the bottom of the screen are five buttons. The button furthest to the left displays the universal symbol for "Record," and pressing that button brings up the iPad's video recording interface. The user can then record and save a video to the camera roll. After saving a video and exiting the video interface, a thumbnail of the video is displayed on the screen. The next button displays the universal symbol for "Play," and pressing that button plays back the last recorded video on the full screen. The next button, which has the image of a floppy disk, is the "Save" button. Currently, this button brings up the iPad's camera roll in a popover, but future iterations of the app will allow the user to upload the video and exercise information to a secure server by pressing this button. The next button brings up the iPad's camera interface. This allows the user to take a still photo. Upon saving the photo to the camera roll, the photo is displayed on the screen. The final button, which has the image of a trash can, is the "Delete" button. Pressing this button clears all text fields and also clears the thumbnail image from the screen.

The app was created in Xcode and written in Objective-C, the programming language Apple uses for iOS. Software testing was done using both the iOS Simulator built into Xcode and an actual iPad. Testing on the iPad required purchasing an Apple Developer's license for $99; this was the only cost of the project. Ease of use testing was conducted in a mock clinical setting at Penn State Hershey Medical Center.

KNEE JOINT FOR ASSISTIVE LEG BRACE

Designers: Darren Deltondo, James Gault, Alec Tanida, Mike Testa, Christina Webber
Client Coordinator: Dr. Everett Hills
Penn State Hershey Rehabilitation Hospital
Supervising Professor: Margaret Slattery Ph.D.
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INTRODUCTION

One of Dr. Hills' patients sustained major nerve damage in an accident years ago. As a result, his right leg from the quadriceps down to his foot has been permanently paralyzed and he must wear a locked full leg brace, allowing him to stand. However, in the past, this existing brace has caused many problems for the patient, including forcing him to walk with an unnatural gait, resulting in hip and lower back pain. The existing brace has failed multiple times because the forces generated by the patient's unnatural gait put torque on the joint.

The Team was tasked with redesigning the brace to fulfill the patient's requests. To allow for more natural gait, the patient required a brace that can swing freely only from zero to six degrees of flexion. The maximum flexion while standing is six degrees, allowing the patient to stand up straighter and aid in reducing lower back and hip pain. Finally, the brace will be redesigned to reduce the incidence of failure.

A market search was performed to find existing braces that fit the design problem. No such braces were found, so the Team focused their efforts on redesigning the joint of the existing brace. The existing joint was cut out of the brace and replaced with the newly designed joint. Photos of the final prototype are shown in Figure 12.14.

Fig. 12.14. A) The Final Brace Prototype. B) Close-up Image of the Replaced Knee Joint Mechanism.

SUMMARY OF IMACT

It is important to design high quality devices for people with disabilities. Many people were born with disabilities while others may have suffered from accidents. Regardless, disabilities should not stop people from living normal, productive lives. In this case, the patient was a healthy, hardworking person who happened to be in the wrong place at the wrong time. Existing braces do not help him in his specific circumstance so the Team developed a device to help him to return to the life he led before the accident. The brace will allow him to slightly bend his paralyzed leg so he can walk more naturally. The patient and sponsor found the brace practical and fully functional.

TECHNICAL DESCRIPTION

The leg brace was created from two main components: an existing, custom fit leg brace provided by the patient, and a titanium slab. The joint was created so that the range of flexion will be limited from zero six degrees when walking. This joint also allows the user to pull a quick release to unlatch the joint, allowing the knee to flex from 0 to 90 degrees for safety and comfort requirements.

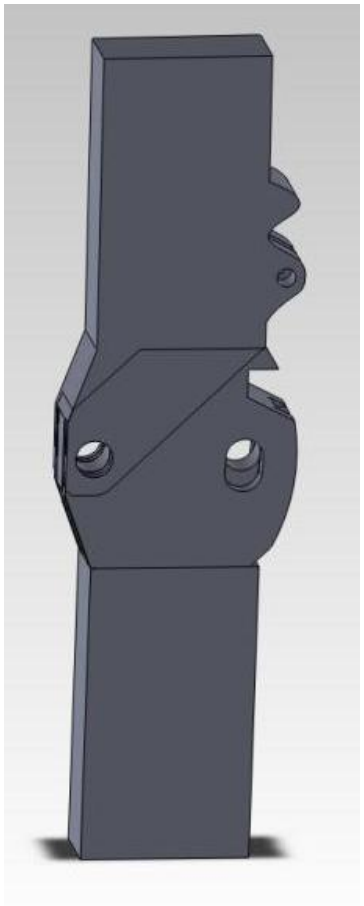

Fig. 12.15. Assembled joint attached to brace.

The joint was initially created using SolidWorks for 3D imaging and planning purposes, as well as for use in Finite Element Analysis. The design consists of three main parts: the femoral component, the primary tibial component and the secondary tibial component.

The femoral component and secondary tibial component are mounted to the upper brace and lower brace, respectively. The slot on the right hand side of the primary tibial component restricts the motion of the joint to zero to six degrees when it hits a pin placed in the right hole in the secondary tibial component. The joint swings from 0 to 90 degrees when the latch mounted on the brace is released from the overhang on the top, right portion of the primary tibial component. Additionally, each joint requires 13 man-hours to machine and the assembled joint is shown in Figure 12.14.

Finite element analysis was performed on the joint to ensure it can support the weight of the patient. A load of 800 pounds was applied to each component to obtain a von Mises stress field and to look for the area in the design where failure could happen. In Figures 12.16 and 12.17, the von Mises stress fields in the two most important components are shown. Note that the deformation is exaggerated to better visualize the small deformation in the device.

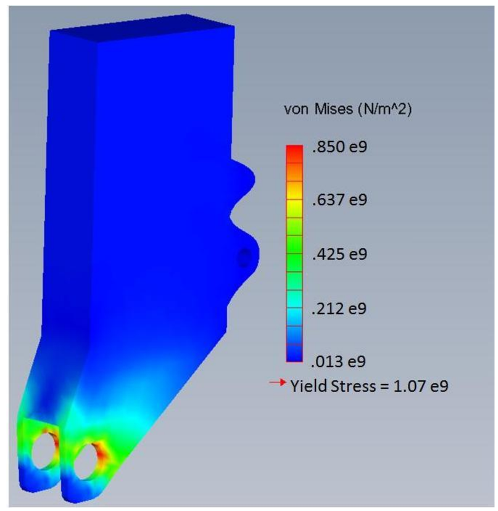

Fig. 12.16. Femoral Component under 800 Pounds.

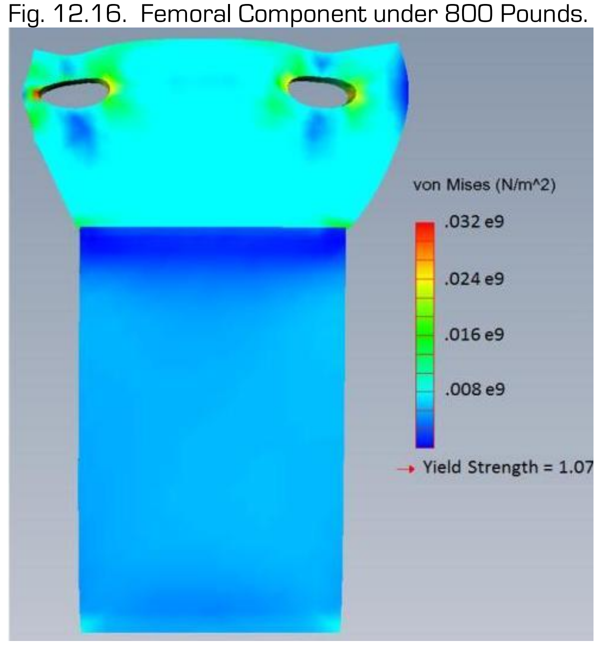

Fig. 12.17. Secondary Tibial Component under 800 Pounds.

MOTORIZED ROLLING WALKER

Designers: Camilo Arenas, Nick Grassetti, Griffin Lynch, Kayvon Mirdamadi, Jonathan Yoder
Client Coordinator: Dr. Everett Hills
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Supervising Professor: Jason Moore Ph.D.
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INTRODUCTION

The scope of this project was to motorize a standard rolling walker to be used by a patient with partial paralysis in his right hip and knee. The motorized walker provides support and stability to the patient while allowing him to focus on his steps and leg motion instead of focusing on propelling the walker forward. The walker also needed to be practical, reliable, and visually pleasing since the project was going to be used for rehabilitation after the semester ended.

The team used a system of hub motors, a finger trigger throttle, a light weight lithium-ion battery, and a pulse width modulator controller to produce the movement for the walker. The hub motors allowed the walker to operate while maintaining an exterior width that was small enough to fit through doors and an interior width large enough to allow for leg movement. The lithium-ion battery weighs less than three pounds and is easily accessible for charging. The finger throttle allows the patient to operate the walker at variable speeds to adjust for his/her walking pace. Currently, there are not any motorized walker options that exist on the market which allow for the same leg movement as the model that Team Hermes built. An image of the prototype is shown in Figure 12.18.

Fig. 12.18. Photo of the Motorized Rolling Walker Prototype.

SUMMARY OF IMPACT

It is very simple to see how the motorized rolling walker will improved the life of our patient, Mr. Cliff Anderson. When Team Hermes first met Mr. Anderson back in January, his walking routine consisted of concentrating on every step he took as well as pushing the walker forward after every one of these steps. Continuously walking this way requires an extreme amount of energy and focus in order to avoid tripping.

The motorized rolling walker provides the user with safety and comfort while using it to transport in between places. This product will help Mr. Anderson's rehabilitation process by allowing him to take pressure off of his leg and it gives him the freedom to walk at a more constant pace. "Anybody with a walking disability should invest in one of these", said Mr. Anderson after testing the motorized rolling walker for the very first time. Our group hopes this more consistent walking motion will allow him to continue healing, strengthening, and improving the flexibility of his leg muscles and may eliminate the need of a walker in the future.

TECHNICAL DESCRIPTION

The design of the motorized walker focused around the hub motors, which was the major component used to solve the problem. Our motorized walker design also incorporates a very user-friendly acceleration mechanism, a dual brake system, a pulse width modular controller to properly operate the hub motors, and a long-lasting battery that can be easily charged. The 60W 12V hub motors, that our team chose to provide the walker's motion, were internally gear down to produce a maximum speed of 3 mph. These hub motors efficiently produced plenty of torque, which was capable of easily moving the walker up an incline with a 300 pound load on the seat. To adjust the speed of the hub motors, we used a rotational potentiometer as the system's input. This trigger rotates 50° which instructs the motor to go from stop to full speed and is sprung back to "zero speed" with an internal spring. The potentiometer is the input for the pulse width modulator controller. The coupling of these two components properly and efficiently control the speed of the hub motor. The system is powered by a light weight lithium ion battery. Weighing in at only 2.5 pounds, this 12V 18Ah battery provides the user with approximately 5 hours of use. The status of the entire system is monitored by the battery condition meter that visually informs the user when the voltage of the battery is dropping and should be recharged. Various toggle switches are also incorporated within the circuit to shut off power to the entire system or each hub motor separately, which provides the user with several operating set-ups.

From the research the team has done and from the interviews with Mr. Anderson, the group has also learned there are many other minor features that need to be integrated on the walker to improve its functionality. Since the user of a walker can have a wide range of leg movement limitations, the team felt that it was necessary to increase the inner width of the rear of the walker to around 17-19". This will decrease the chance of the user's foot hitting the wheel and provide more room to walk in between the rear posts. A walker is also used in many different environments. An average door in the United States is 32" inches wide, so we kept the overall width of walker under that to reduce the risk of the walker not being able to easily fit through the standard doors. The wheels also need to be able to work properly on multiple common surfaces. An adequate amount of friction between the wheel and surface is needed to ensure the wheel does not slide during braking, which is why the outer part of the wheel will be made from a rubber material. The outer diameter of the wheel will also be large enough to smoothly roll over cracks and other small obstacles. This translates into a wheel size of 8" to 12" in diameter. To make the user feel more comfortable moving and turning the walker, the front wheels should be able to spin and the rear wheels should be fixed. This is a common steering setup found in other products such as cars and bikes. Other minor product features that our design will feature includes telescoping arms, comfortable handle grips, folding for storage, low noise, and a nice visual appeal.

Various analyses and tests were performed on the walker and it's components to ensure it would operate as we had designed. Before purchasing the hub motors, our team calculated the average resistance force that the motors would have to overcome to move the walker. To fit the new, bigger, hub motors onto the walker our team had to design new rear forks. Once a design was chosen upon and modeled in SolidWorks, simulations were performed to determine the approximate factor of safety and deflection. After a prototype of the walker was manufactured, our team used an ammeter to test for the current system under various conditions. These amperage readings let us determine the proper battery capacity for the walker to provide the user with 4-5 hours of operation.

To start the project our team was supplied with an existing "Rollator" style walker to modify, which is sold for around $400. To manufacture the final product our team purchased several relatively expensive products which included the hub motors that were $165 a piece, the controller which was $100, the trigger throttle which was $32, the battery which was $135, the battery charger which was $60, and the battery condition meter which was $15. To construct the walker prototype the team used material from the Learning Factory and the water jet which can be estimated to cost a total of $100. The team also needed to purchase various electronic supplies such as rocker switches, fuses, and wiring that cost around $30.

RECREATIONAL EQUIPMENT OF BILATERAL AMPUTEES

Designers: Jesse Addis, Aaron Cheung, Dylan Sirgiovanni, Erin Viscito and Sharon Waxmonsky
Client Coordinator: Diane Matter
Supervising Professor: Jason Moore, Ph.D.
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INTRODUCTION

The objective of this project is to design a device that will allow bilateral amputees to participate in various recreational activities. This project is specifically for an amputee who aspires to golf, fish, and garden independently, but the team hopes the device will be used by other amputees as well. Because amputees cannot grip cylindrical rods with their prostheses, the device will hold rods of various diameters and stabilize them through arm movement. The device will also be light weight, easy to use, low cost, and durable to meet user needs.

There are currently no devices on the market which match the versatility of the device created by Team Limb-itless. Although other adaptations exist, they are typically intended for a single application and often cannot be used by bilateral amputees. Current devices often hinder the user's independence by significantly altering the prosthetic; this may include removing essential portions of the prosthetic or otherwise altering the prosthetic in a way which prevents normal use. Problems presented by these alterations are further compounded by the inability of the user to remove the adaptation independently.

In order for the user to have independence when attaching and detaching the Team Limb-itless device, it is sectioned into a permanent base attached to the prosthetic and a detachable body. After considering several different design concepts, Team Limb-itless decided to use a two ratchet system. The ratchets are a mechanism that an amputee can easily use independently. Figure 12.19 shows a schematic of the final prototype. The team tested that the ratchets will exert enough force on the rod to prevent slipping and rotation.

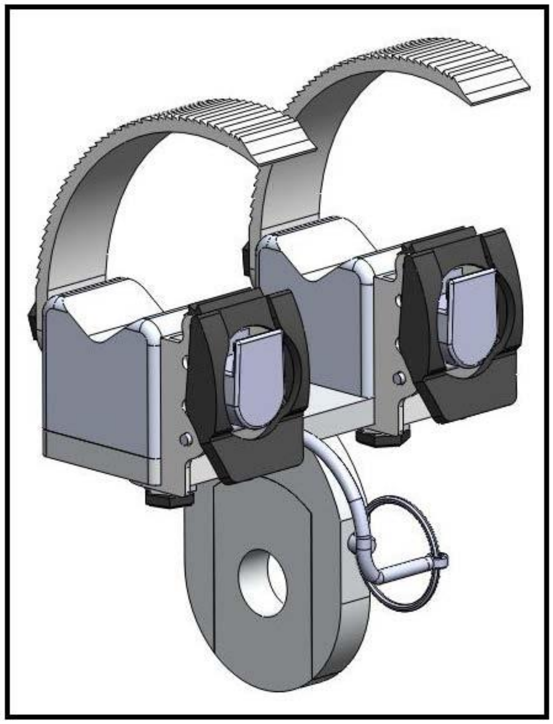

Fig. 12.19. Schematic of the Device Design.

SUMMARY OF IMPACT

Overall Diane is satisfied with the final device design. It was successfully used as a part of the "First Swing" Golf Clinic held on April 23, 2012. During the clinic the device was scrutinized by a number of medical professionals (physical therapists and kinesiology students) as well as potential users, all of whom received the device positively. Team Limb-itless feels that the device successfully met all of the intended design specifications and customer needs. The device holds a range of cylindrical rods (0.7-1.4") in a secure manner suitable for typical use. The device can be easily used and removed independently and does not add considerable burden to the user.

TECHNICAL DESCRIPTION

The design features a semicircular permanent base that attaches to the existing wrist prosthetic and a body containing V shaped plates, ratchets, and straps which secure the recreational device. The body of the device secures around the base through attachment of Base A over Base B, this connection is then further secured through a removable pin. The V shaped plates on the body align the recreational device so that the straps can be wrapped around the device and inserted into the ratchets by the user. This is show in Figure 12.20. The total cost of the device components was $59.25.

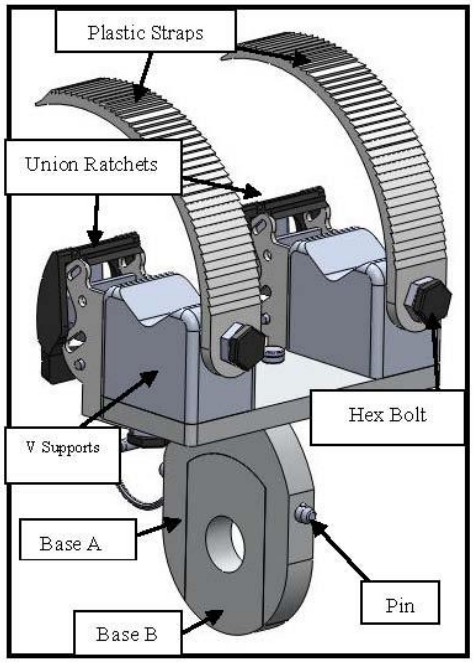

Fig. 12.20. Schematic of the Final Device Prototype with Labeled Components.

SOCK AND AWE: ASSISTIVE DEVICES

Designers: Corey R. Bauer, Courtney P. Haskins, Thomas A. Hyde, Philip Swaney, and Jared S. Wineberg
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College of Medicine and Rehabilitation Hospital
Supervising Professor: Dr. Mary Frecker
Department of Mechanical and Nuclear Engineering
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INTRODUCTION

There is currently no efficient device on the market today for a paraplegic patient to put on both socks and shoes independently. The design team has proposed a single device that will accomplish both tasks quickly with minimal effort required by the user. A prototype is shown in Figure 12.21. Such a device could assist the roughly 125,000 paraplegics in the United States with this everyday task that is often taken for granted. Through talking with Clifford Anderson, a paraplegic who was the chief user of the prototype, the customer needs were determined. The device should be compact, ergonomic and durable for extended use, simple to use, and safe. Having used sock aiding devices and grippers that are currently on the market, Mr. Anderson identified the advantages and disadvantages of existing devices. While the Gripper is multifunctional and relatively easy to use, it lacks durability and offers limited assistance for putting on socks and shoes. The Sock Aid is easy to use, durable, but only assists in putting on socks. A device for putting on both socks and shoes would be more efficient.

SUMMARY OF IMPACT

The assistive device designed by the team was well received by the project sponsor as well as Mr. Anderson. Using the device, Mr. Anderson was able to successfully put on his socks with no assistance. He described the functionality of the sock donning device as "outstanding." Although he was not able to use the shoe donning portion of the device due to his limited ankle flexibility and lack of adjustability on the device, he did say that "if you have a person that has the bend in their ankle and the movement in their leg to push out, [the SS Donner] is perfect." Both Dr. Hills (project sponsor) and Mr. Anderson agreed that the design would be functional for a large number of paraplegics who do not have the same ankle limitation as Mr. Anderson. The device met the

Fig. 12.21. Prototype of the Sock and Shoe Assistive Device.

majority of the customer needs as well. It was durable, inexpensive, and easy to use. Lastly, because the materials used in the prototypes are inexpensive and quite common, the device could be manufactured at a low cost to assist paraplegics who do not have the financial resources to purchase assistive devices.

TECHNICAL DESCRIPTION

The design worked in the following manner: First, the user attached the sock or shoe to its respective platform (the sock would be placed over the U-shaped platform, while the shoe would be secured to the shoe platform using the toe "cup"). The arm extenders attached to the platform, and were then used to place the guide pins (which were also attached to the platform) into the track. After the guide pins were placed into the track, the user loaded his or her foot onto the leg rest and pulled on the arm extenders to move the platform along a predefined path, towards the foot. The force applied by the user was directed by the track so as to mimic the natural motion of putting on a sock or shoe. Once the sock or shoe was securely attached to the foot, the user used the arm extenders to push the platform away from the foot.

Pictured in Figure 12.22 is a detailed Solidworks model of the device. All parts can be seen here: the leg rest, guide pins, predefined path, shoe platform, toe cup, and arm extenders. The device was constructed mainly out of wood, due to its relatively low cost and easy machinability. Moving forward, there are several major changes that should be implemented. Increased adjustability of the device in order to allow users of different heights to use the device is vital. Specifically, the leg support should be able to be adjusted in the vertical direction, the arm extenders need to be adjustable in the vertical direction, and the track should have multiple paths that the platform can follow to accommodate more users. Second, the device needs to be slimmed down while still retaining the track aspect to the design. Eliminating material and lowering the tracks to save space can achieve this. Lastly, the track shape can be refined to allow for different approach angles onto the foot, which will also aid the adjustability of the device.

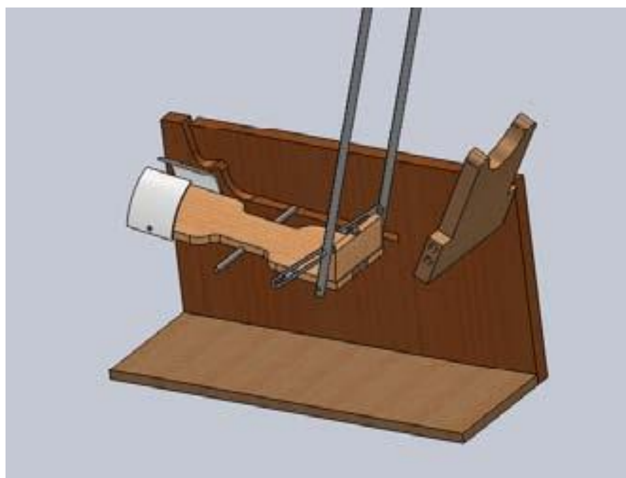

Fig. 12.22. Solidworks Model of the Sock and Shoe Assistive Device.

TEAM STAIRCLIMBER TO HEAVEN

Designers: Dan Morris, Sam Tubiello, Tomoki Sato and Brian Ham
Client Coordinator: Dr. Everett Hills
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Central Pennsylvania Spinal Cord Injury Support Group
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Supervising Professor: Dr. Mary Frecker
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INTRODUCTION

There are many difficulties that people confined to the use of a wheelchair face every day. A main inconvenience of a wheelchair is the fact that they do not allow the user to travel anywhere they want, independently, all the time. Ascending and descending stairs is a challenge that many wheelchair users will face for the rest of their lives unless new ideas are established and developed to create a better wheelchair. This is the main reason why the Hershey Medical Center in association with the Central PA Spinal Support Group has assigned the task of developing a more complete, independent, user friendly, portable wheelchair capable of ascending and descending stairs.

Team Stairclimber to Heaven's main objective involves on improving last year's senior design project performed by the TRASC Wheelchair Mobility System team. The three most important revisions to last year's design involve steering, weight distribution, and a less damaging tread design. A vast improvement made to last year's design is that the Stairclimber allows the user to turn, thus making the machine operational on not only straight stairways but typical ones with landings that require 180 degree turns. Other stair climbers on the market, such as the Stairmax or the iBot, are extremely expensive and cost on average $30,000. Team Stairclimber to Heaven developed a Stairclimber that costs under $1,000.

SUMMARY OF IMPACT

Team Stairclimber to Heaven has developed a machine that will better the life of many paraplegics. The ultimate goal of almost every paraplegic is to be as independent from other friends and family as possible. Clifford Anderson, a paraplegic interviewed stated, "If you could create a machine that can transport me upstairs and still be affordable than I along with the rest of physically disabled persons would be jumping for joy!" Climbing stairs before the development of stair climbers was always a tedious process but now with continued development of the Stairclimber, paraplegics may be able to use a reasonably priced device to traverse stairs.

Fig. 12.23. The Stairclimber with an Attached Wheelchair.

TECHNICAL DESCRIPTION

To operate the Stairclimber, the user will position the seat of their wheelchair over plate A, as shown in Figure 12.24. The user then uses the actuators (Figure 12.24 label B) which tilt the wheelchair back onto support posts and rest (Figure 12.24 label C). The seat rest is equipped with clamps to secure the wheelchair. The seat rest is angled so the wheelchair seat will be horizontal when climbing stairs. Two winch motors will control the movement of the Stairclimber. When operating in unison, they will cause straight translational motion forwards or backwards. The motors can also oppose each other, which will cause the Stairclimber to rotate, allowing it to turn. The motors rotate the driving sprocket (Figure 12.24 label D). All the other sprockets are idler sprockets that serve to keep the track taught. When ascending stairs, the portion of track labeled E will be facing the staircase. The angle of this part of the track matches the angle of a standard staircase, allowing the ridges on the track to grip the first stair and begin the Stairclimber's ascension.

The Stairclimber succeeded in many of its objectives to improve upon last year's design. Due to its wood and aluminum frame, the Stairclimber is smaller and lighter than the previous design, while still strong enough to support a wheelchair and user. The polyurethane grippers were lighter and gentler on floor surfaces than the previous design's aluminum grippers. The two ATTV winches reduced cost as well as gave the Stairclimber the ability to turn. This makes the Stairclimber useful on staircases with landings, or sharp turns at the bottom or top. All this was done with $866, about a third of the budget of last year's team. However, the Stairclimber was not a total success. Due to setbacks that occurred during the last two weeks of the semester, the Stairclimber never ascended a full staircase. Silver soldering was the chosen method off connecting the drive shaft to the drive gear in the ATV winch. While this bond was strong enough to allow the Stairclimber to travel on flat ground, the stress of traversing up a staircase was too great, and broke the connection between the gear and shaft. Despite the limitations of the prototype, the sponsors were very impressed and pleased with the team's progress. Dr. Hills and Nancy were both in attendance at the design showcase, and their reactions to the Stairclimber were very positive. The Stairclimber's ground mobility, as well as the new tracks were their favorite features. Dr. Hills and Nancy were amazed when one team member lifted and held the Stairclimber by himself. This demonstrated the portability of the new design, as well as how much lighter the new design was than last years.

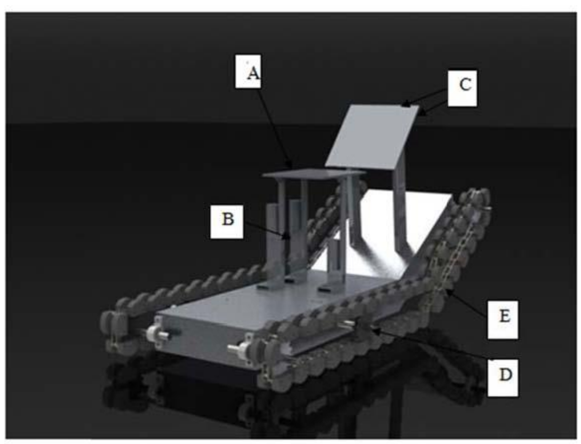

Fig. 12.24. Stairclimber to Heaven Schematic

CHAPTER 13
ROCHESTER INSTITUTE OF TECHNOLOGY

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MOTION ASSISTIVE DEVICE FOR SAILING

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INTRODUCTION

The goal of this project is to re-design, build, and test a portable, detachable seating system that will allow disabled users to participate in IFDS (International Association for Disabled Sailing) competitive sailing events. During an IFDS sailing competition, each team is allowed 3 users per boat, who must each meet the criteria of eligibility. The team needs to maximize the functionality of each individual while minimizing the weight being carried on the boat. A sailor with double below-the-knee amputations had previously used a benchmark device, and the client sought a modified device that could be used by a C4-5 quadriplegic user. The system was required to use the sailor's rotational arm motion to steer the boat's rudder, and to allow adjustment of the user's position by rotating along a bearing mounted track for leverage and view during sailing scenarios. The team was charged with reducing excess weight, increasing functionality, and adapting the device specifically for a C 4-5 quadriplegic user. The final product contains a significantly improved system that still controls the boat's rudder and moves around an arched track while safely securing the user.

SUMMARY OF IMPACT

The team has designed a new system that fits into a Sonar keelboat without modifications to the boat, and that can be custom fit for a new user. The system features a 17 % weight reduction (18 lb.), a user force amplification from a 20 lb. input force to a 128 lb. working force, entry time reduced from 30 minutes to 11 minutes, detachment time reduced 5 minutes to less than 25 seconds, reduction of lines tangling during operations, and wider angle of view for the user when rotating around the track. The customer is training for the 2016 Paralympic Games and plans to start a nonprofit organization, involving community sailing centers. "If they don't already have a community sailing program, or an adaptive program for people with disabilities, I'm going to propose that

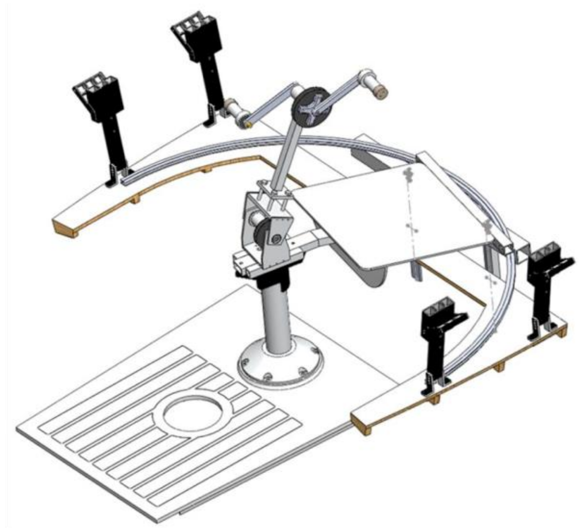

Fig. 13.1. CAD Model of Motion Assistive Device for Sailing.

Fig. 13.2. Client Participating in Final Fitting Session.

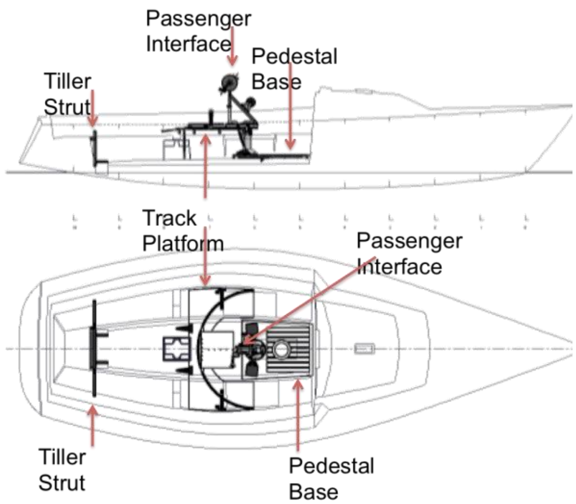

Fig. 13.3. Full System Design.

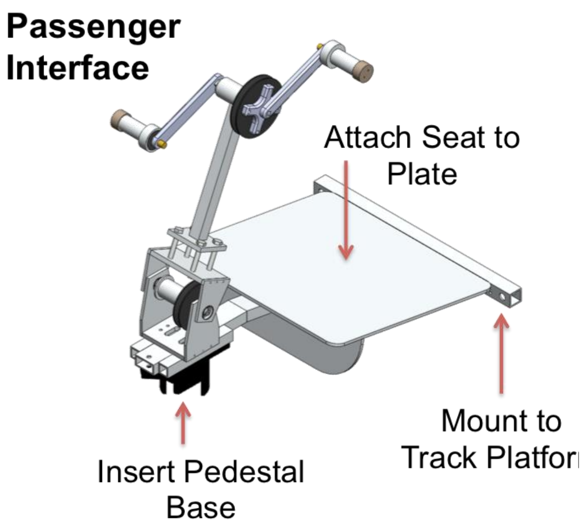

Fig. 13.4. Passenger Interface Detail.

they start one – using this equipment as a way to do that."

TECHNICAL DESCRIPTION

The core design decisions that the team made that influenced the design of the entire system were (1) to choose corrosion-resistant materials with relatively high strength-to-weight ratios and (2) to custom-fit the design to the customer's particular body size and shape, while building in adjustability for other users. The team used primarily 6061-T6 Al, stainless steel, and marine-grade plywood for construction, and brought the customer in for two fitting sessions.

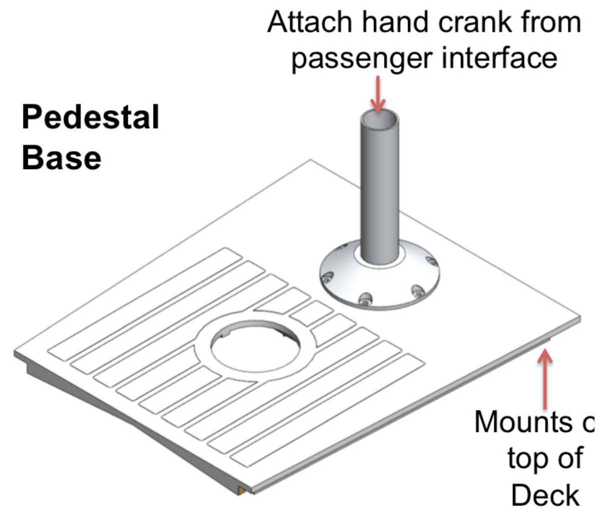

Fig. 13.5. Pedestal Base Detail.

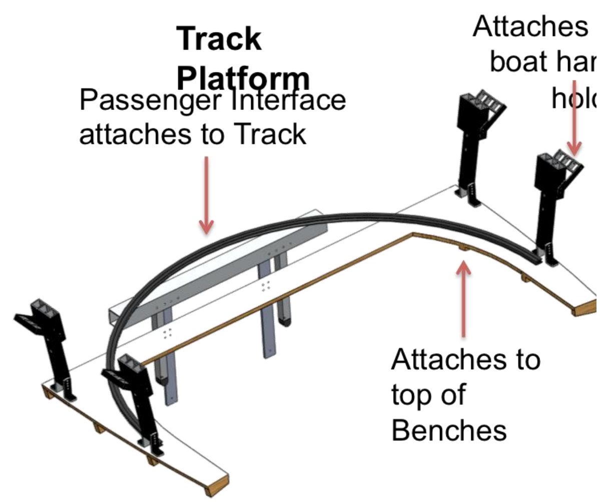

Fig. 13.6. Curved Track Platform Detail.

The team broke this problem into several distinct, yet inter-related parts: passenger interface, track platform, pedestal base, and tiller strut (Figure 13.3). The passenger interface (Figure 13.4) consists of a hand-crank, which allows the user to control the tiller, and a mounting plate for the seat. The base of the crank attaches to a pedestal base (Figure 13.5) and the seat plate rides along a curved track (Figure 13.6), which allows the user to shift his weight from side to side, while providing him with good visibility of boat operations. Finally, the tiller strut guides and helps to tension the lines from the crank to the tiller arm.

All components were analyzed to ensure that they would not fail under loading in-service. In order to accomplish this, the team simulated both nominal loading and worst-case loading. Nominal loading

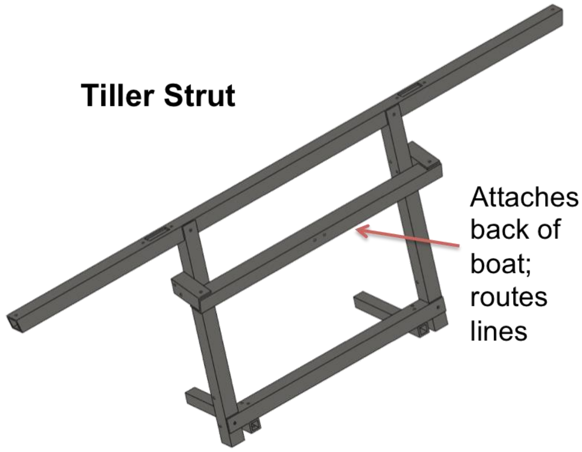

Fig. 13.7. Tiller Strut Detail.

was based on the user's weight, the amount of force he is capable of applying with his arms, and the amount of force the system sees due to the mechanical advantage designed into the system. The worst-case loading was determined by using either a worst-case customer position or a worst-case sailing condition. Some examples of these would be the failure of a seat mount, leaving the user's entire weight hanging from the crank where his hands clip in; 40-knot winds and the associated high seas, or the user weight forced to one side of the system due to the boat leaning in rough seas. Using ANSYS Workbench and the distortion energy yield criterion, the team performed complete analysis of the system to determine nominal and worst-case factors of safety. A summary of all critical factors of safety against yielding is presented in Table 13.1.

Table 13.1. Summary of Critical Component Stress Analysis.

Crank System	**Load (lb)**	**Deformation (in)**	**F.O.S.**
Case #1 (Normal Operation)	20	0.019	8.82
Case #2 (Pulling away Crank)	170	0.162	1.04
Case #3 (Falling onto Crank)	-170	0.162	1.04
Seat Plate	**Pressure (psi)**	**Deformation (in)**	**F.O.S.**
Case #1 (evenly distributed user weight)	0.4722	0.022678	30.4
Case #2 (weight distribution during rotation)	0.9444	0.045355	15.45
Tiller Strut	**Load (lb)**	**Deformation (in)**	**F.O.S.**
Case #1 (Going Straight)	150	0.06	2.09
Case #2 (Turning Left)	150	0.12	1.18
Case #2 (Turning Right)	150	0.12	1.23

A summary of the team's final result against specifications is presented in Table X.2. The only specification that the team failed to meet was that of a functioning rearview mirror, and this was eliminated from the design because its presence was deemed unsafe to other sailors on the boat. The system has been installed on the boat and is now being used for training.

Total cost was approximately $2800.00, with $500 of support coming from the RIT Multidisciplinary Senior Design Program.

More Information available at http://edge.rit.edu/content/P12031/public/Home

Table 13.2. Test Results Against Specifications.

Engineering Specification	Unit	Target	Ideal	Actual	Pass/ Fail
Weight and Cost					
Weight of each part combined	lb	<106	<79.5	**88**	Pass
Cost of components purchased	$	<$3000	<$2400	**2800+**	Pass
User Comfort					
Distance between hand attachment points	in	18±2	18±.5	**17**	Pass
Height of crank relative to the bottom of the seat	in	18±2	18±.5	**19**	Pass
User Specified Harness	Binary	Yes	Yes	**Yes**	Pass
Comfort perceived by user from 1[low]-10[high]	#	>5	10	**7**	Pass
Installation					
Volume of disassembled and packed unit	in^3	<74,088	<66,679	**37,800**	Pass
Secure to Sonar with non-permanent attachments	Binary	Yes	Yes	**Yes**	Pass
Time required for entry	minutes	<60	<30	**11**	Pass
Performance in Normal Sailing Conditions					
Degree of movement of Rudder from centerline	degrees	>40	>90	**46.6**	Pass
Backlash in the lines controlling the Rudder	in	<1	<0.5	**1**	Pass
Location of Track Platform respective to Keel	(x,y) in	0±15,0	0±10,0	**13**	Pass
Percentage of amplification of user's force input	%	>0	>30	**50**	Pass
Time required to detach hands	seconds	<60	<30	**5**	Pass
Angle of tilt of chair relative to horizontal plane	degrees	>10	>15	**20.2**	Pass
Functioning rearview mirror	Binary	Yes	Yes	**No**	Fail
Performance in Rough Sailing and Worst-Case Conditions					
Corrosion resistance	Binary	Yes	Yes	**Yes**	Pass
Minimum FOS of critical elements found via analysis	#	>1	>3	**1.04**	Pass
Time required to release user from seat and system	minutes	<10	<5	**0 .42**	Pass
Functioning emergency override for Rudder	Binary	Yes	Yes	**Yes**	Pass
Clearance of tangle prone lines from chair swinging	in	>1	>4	**7**	Pass

SEATED BALANCE TRAINING GAME

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Computer Engineering Designer: Alfred Lee
Client Coordinator: J.J. Mowder-Tinney, PT, PhD
Supervising Professor: Dr. Elizabeth DeBartolo
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INTRODUCTION

The Balance Tower Training Game (see Figure 13.8a) is a continuation of a previous project designed as a rehabilitation device for people using wheelchairs. The goal of the project is to allow people using wheelchairs to train their core muscles without the need for multiple therapists, which the clients have said will increase their feeling of independence. Current methods for muscle training require the client to reach for a therapist's hands, where a second therapist supports the client. The new balance towers designed under this project allow for the same kind of muscle training with only one therapist required.

SUMMARY OF IMPACT

Although a goal of the project was to design and build two functioning towers, the second being used in conjunction with the first, the team could only complete one tower due to unexpected obstacles. The final tower operates in close accordance with the client's request, allowing for the strengthening of core muscles through reaching while giving feedback to the user (through the use of LEDs seen in Figure 13.8b). Between the old and new versions of the tower there is no loss of features, and there have been significant improvements made to wire organization and reduction, and future expandability. Although the outer shell of the tower remained unchanged, a new Micro Controller Unit (MCU) would support future wireless communication with a second tower (adding additional degrees of motion when reaching) and also potential new game types. Currently, only two game types exist, Timed Trial and Random, which both have relatively short game times.

TECHNICAL DESCRIPTION

The Balance Tower Training Game is comprised of six major components: 1) the outer structure, including the aluminum touch plates, 2) comparator circuits to determine whether a panel has been touched or not, 3) a printed circuit board (PCB), 4) a LCD display, 5) LED banks, and 6) the MCU. The MCU is the brain of the tower, taking in information from the comparator circuits and user controls and then outputting data accordingly to the LEDs and LCD screen. The LCD unit has three buttons with which the operator (in this case the therapist) can select the game type and various options associated with the specific game picked (Figure 13.8c). This information is sent to the MCU which begins the game processes, and will run the selected game for the given amount of time or until a certain number of rounds is reached.

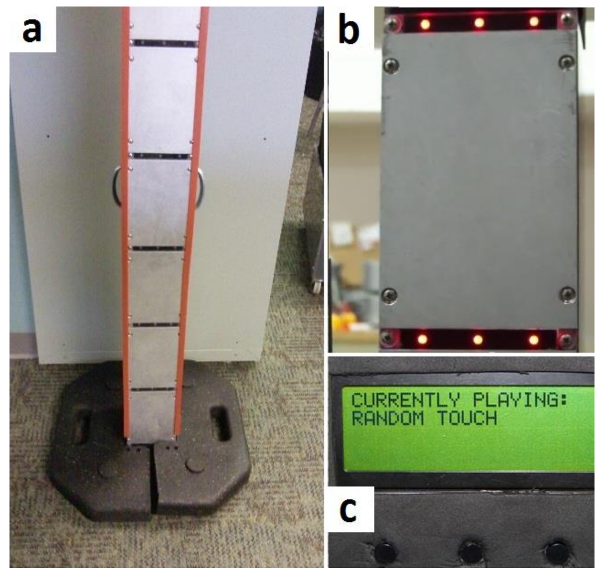

Fig. 13.8. Tower and Components: (a) Whole Tower Assembly, (b) Two LED Banks Signaling the Touch Plate was not Pressed in Time, and (c) LCD Display Showing the Game Type.

The user's goal is to touch the panel that sits between the illuminated (blue) LED banks; upon touching a plate and grounding it (all plates are active) a comparator circuit behind the plate sends a signal to the MCU, which then decides if the correct plate was touched. The MCU then proceeds to select a new plate to be lit up, and the game continues. Upon completion of a game the results are displayed on the LCD screen and the client is given the option to play again. In the future, the device will be able to interface with a printer, printing the results for each game. Finally, in order to accommodate the user requirement for a functional reach test, the team affixed a tape measure to the side of the tower at shoulder height for a person seated in a wheelchair.

Since power cables and other wiring on the floor would be tripping hazards, and would make the apparatus less mobile, the team opted for a completely wireless tower solution. The final tower operates on 4AA batteries for the MCU, touch panels, and LEDs, and one 9V battery for the LCD display. The system can operate for up to 28 hours on these batteries. Additionally, communication between the two towers will be wireless.

Due to licensing issues with the previous programming environment, the team chose to replace the old MSP430 with a new MSP-EXP430F543A board that met or exceeded the requirements of the previous MCU. The team chose the EZ430-RF2500 wireless communication device, which is compatible with the MCU, and which would serve as a link between the two towers, once they were both operational.

The comparator circuit (See Figure 13.9) was not an original feature of the tower, but turned out to be the simplest solution to the incompatibility of the current touch style aluminum plates and the capacitive touch chip. When the patient touched the panel, the comparator circuit would output a high value to the MSU, telling it that a plate had been touched. The redesign includes a custom PCB, which supports the MCU, power regulation, and LEDs. The use of the PCB allowed for better cable management and easier maintenance and troubleshooting. The only issue arising with the comparator circuit for the grounding plates is that users in motorized wheelchairs may be connected electrically to a different ground on their wheelchair. The clinician reports that she has all users in wheelchairs move their feet to the floor for seated balance training, so that they will be on a common ground with the tower.

Future iterations of the balance training tower will include the creation of a second tower, with wireless tower-to-tower communication between the two, as well as tower-to-printer communications. The games can be augmented by programming more games to support different difficulty levels, and the MCU supports the use of an audio system to supplement the visual feedback with auditory feedback.

Total cost was approximately $1354.09

More Information available at http://edge.rit.edu/content/P12005/public/Home

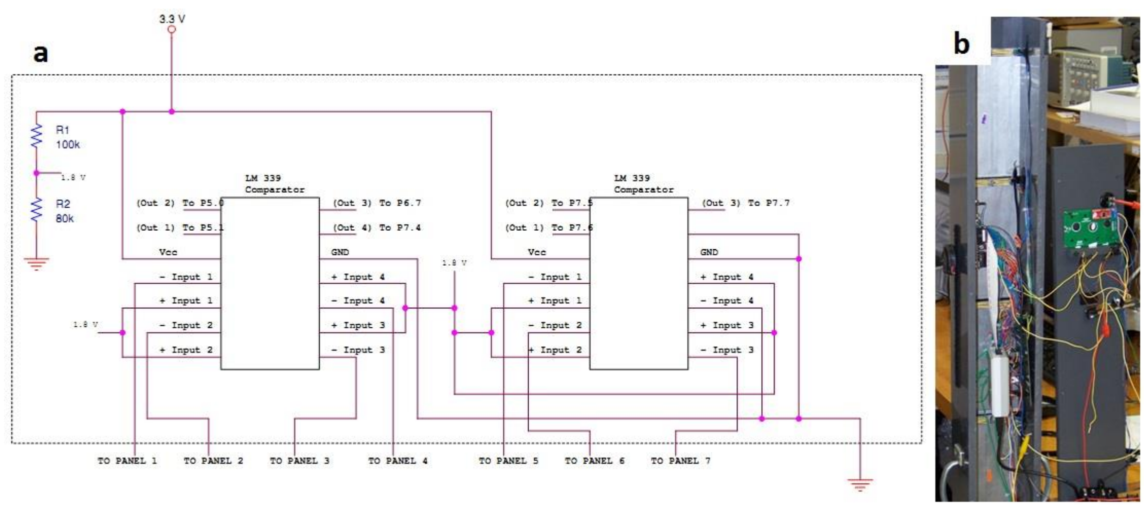

Fig. 13.9 (a) Comparator Circuit Schematic, and (b) PCB (Mounted Within Tower).

TACTILE IN-BUILDING NAVIGATION AID FOR BLIND PEOPLE

Electrical Engineering Designers: David Sachenik, Robert Evans, David Yip, Curtis Beard, Aaliya Shaukat, and David Taubman
Computer Engineering Designers: Jackson Lamp and C. Oliver Wing
Mechanical Engineering Designers: Konrad Ahlin, Stuart Burgess, Jeffrey Chiappone, and Benjamin Davidson
Industrial and Systems Engineering Designers: Muthila Yasin and Robert Steigerwald
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INTRODUCTION

Individuals who are vision- and hearing-impaired can typically use a walking cane or a seeing-eye dog for navigating to familiar places. However, when the place is unfamiliar navigation can become a complicated task, especially since a small number of blind people can read Braille. This project resulted in a hand-free device that will help navigate an individual to a specified location within an unfamiliar building. The device allows the user to type a room number destination on the device keypad, and the user receives tactile feedback directing them towards that destination. The device uses radio-frequency identification (RFID) tags, which can be placed throughout the building, to determine the user's position. If the user is off-course the device will recalculate and provide new direction. This and all other information is output from the device to the user using three shaftless vibrational motors. The overall assembly of the device (Figure 13.10) consists of the PCB (1) and RFID reader (2) stacked within the housing enclosure (3), with the keypad (4) sliding into place on the top half of the plastic housing. The housing is mounted to the elastic sleeve (5) using Velcro with a strap fitting through the bottom and around the arm for a tighter fit. Wires for the vibrational motors (6) are sewn into the elastic sleeve.

SUMMARY OF IMPACT

The final prototype is 3.51x2.47x1.35 in and weighs approximately 4.35 oz., and can operate for approximately 20 minutes on a charge. The device successfully receives destination input from the user, computes a path, and provides directional feedback to the user.

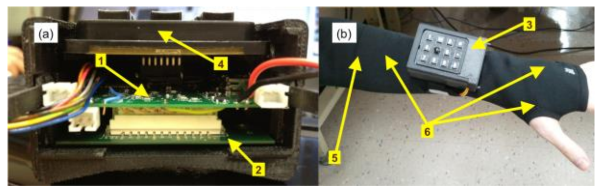

Fig. 13.10 (a) Open Assembly with Stacked Components, and (b) Device Attached to Elastic Sleeve.

TECHNICAL DESCRIPTION

The navigation aid architecture (Figure 13.11) was built around a TI MSP430F5438A microcontroller, and uses a SkyeTek RFID system for detecting user location within a building and a tilt-compensated 3-axis magnetometer to determine user heading. Communication with the RFID reader is accomplished using a SPI interface, and the magnetometer uses I2C. Feedback to the user is provided through three shaftless vibrational motors, controlled by pulse-width modulation. The team chose a rechargeable Li-Ion battery and designed a custom USB charging circuit, a 3.3V power regulator for the MCU, motors, and magnetometer, and a 5V power boost for the RFID reader.

The navigation program consists of a number of components that were developed separately and integrated into a single executable. The map used by the navigation program takes the form of a traditional graph, consisting of a number of nodes connected with unidirectional edges. This structure is augmented by associating RFID tag IDs and destinations with nodes. Nodes, edge, tags, and destinations are stored in separate arrays in ROM and reference one another by index to reduce memory requirements. This map is used by the path-finding

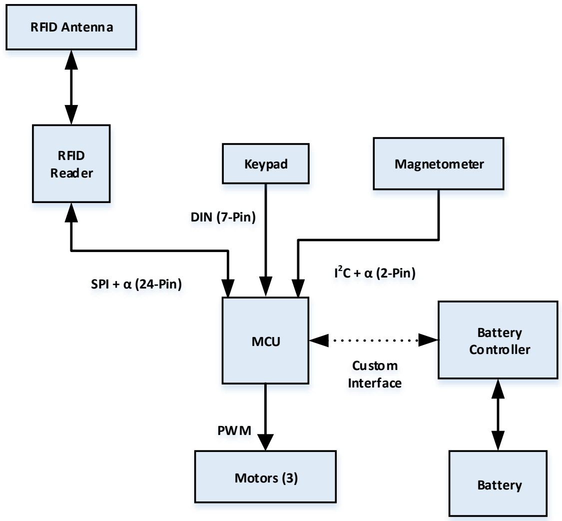

Fig. 13.11. Navigation Aid Hardware Architecture.

algorithm to compute routes between any origin point, represented by an RFID tag, and any destination, represented by a room number. First, an array of proxy nodes is allocated in memory, each element containing the index of the real node they represent and a pointer to another proxy node. Next, Dijkstra's algorithm is run using these proxy nodes, forming a linked list starting at the origin and ending at the destination. This list is stored for use by the path-following algorithm.

The path-following algorithm describes the process used to guide a user using the set of directions generated by the path-finding algorithm. The user's position is first ascertained by polling the RFID reader and checking the list of tags received against the map's tag list. If the algorithm determines that the user is significantly off course, the path is recomputed and the path-following algorithm is restarted; otherwise, the user's position is updated and the algorithm resumes. Next, the user's heading is determined using the magnetometer and is compared against the heading value required for the user to advance to the next node. If these values don't match, the path-following algorithm issues a command to the user to correct their course by turning either left or right. Once the user is facing the desired direction, the command is rescinded. A schematic of the algorithm is shown in Figure 13.12.

Total cost was approximately $601.80

More Information available at http://edge.rit.edu/content/P12016/public/Home

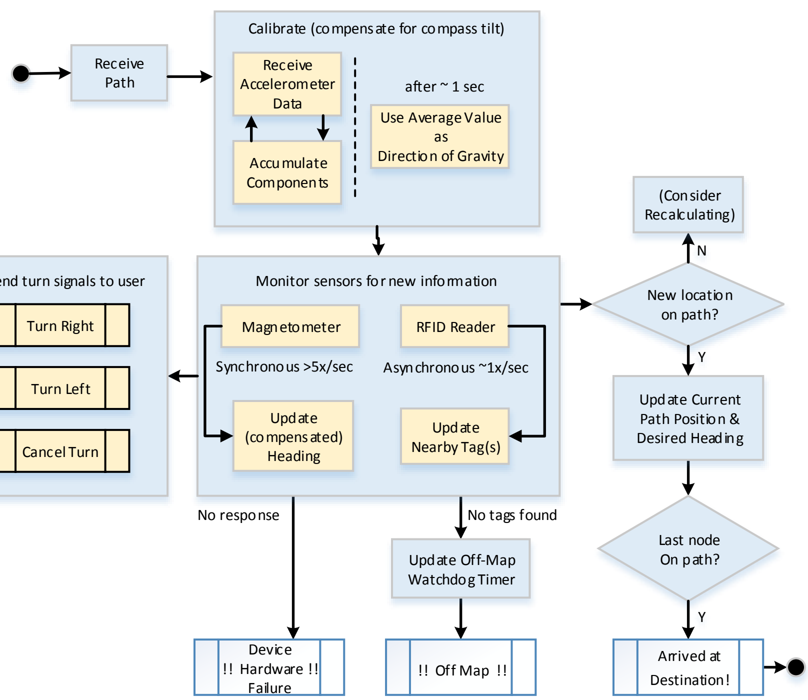

Fig. 13.12. Path Finding and Path Following Algorithm Block Diagram.

ALERT NOTIFICATION DEVICE

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Computer Engineering Designer: Scott Tucker
Mechanical Engineering Designer: Michael Meyer
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Supervising Professor: Prof. George Slack
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INTRODUCTION

The primary objective of this project is to develop a portable, programmable alarm system for the deaf and hard of hearing. The alarm system is a small, pocket-sized device designed to awaken deaf/hard of hearing users with high intensity lights and a bed-shaking device (Figure 13.13). The high-level function of this device is to awaken deaf users in a similar manner to an alarm clock, with a programmed alarm activating the lights and the shaking device. The device features a rechargeable battery, luminous state indication, and a snooze.

SUMMARY OF IMPACT

Currently, deaf and hard-of-hearing individuals must rely on alarm clocks that are large and not particularly portable when traveling. The client coordinator, who is also a potential end user for the device, is looking for a smaller, more portable alarm clock that can be pre-programmed on a computer or cell phone, and that will wake someone using a combination of visual cues and tactile cues. The client was pleased with the progress made on the current device and will continue working on this small-footprint design to make it easy to program through a cell phone's Bluetooth interface.

TECHNICAL DESCRIPTION

The alert notification device was designed around a MSP430BT5190 microcontroller and PAN1325 Bluetooth controller, which provided both a small footprint and low cost. Alarm/notification is provided by a combination of high-intensity LEDs and a purchased bed-shaker that can be powered by plugging it into the alert notification device. Software was developed to control both the LED flashing and the bed-shaker activation. The device is powered by a 3.7V 1250 mAh polymer Li-ion battery, which is regulated to power the MCU and Bluetooth chips, and boosted to 5V for the high-intensity LEDs.

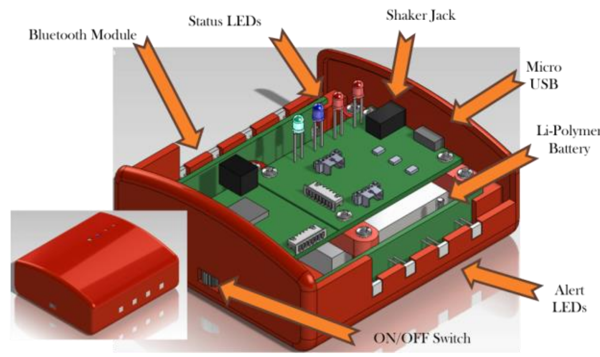

Fig. 13.13. Alert Notification Device Design.

The enclosure for the device was designed to be small, yet strong enough to withstand the forces that could be encountered in a backpack or pocket, while reducing the possibility of overheating. The enclosure, shown in Figure 13.14, was rapid-prototyped using ABS Plastic. The final enclosure is capable of withstanding 100 lb. with a factor of safety of 1.5, and the maximum temperature the enclosed electronics will experience, in an always-on state, is 48ºC. However, in actual operation, the device will be flashing or pulsing the bed-shaker between 1 and 3 Hz for no more than 2-3 minutes, so the always-on operating condition was used as an absolute worst-case scenario.

The team designed a printed circuit board for the MCU and Bluetooth, power, bed-shaker, and control of the LEDs. The PCB consists of top layer, bottom layer, and a silkscreen. This allowed for smaller components and circuitry to be placed on the underside of the board, thus saving precious space. The USB power jack and the bed-shaker barrel jack were kept to one side of the board with final product aesthetics in mind. Most regulation circuitry was kept isolated from everything else in case the board was not printed correctly or a redesign was needed. The

Fig. 13.14. Manufactured Enclosure with MAIN PCB and ONE BANK OF LEDS INSERTED.

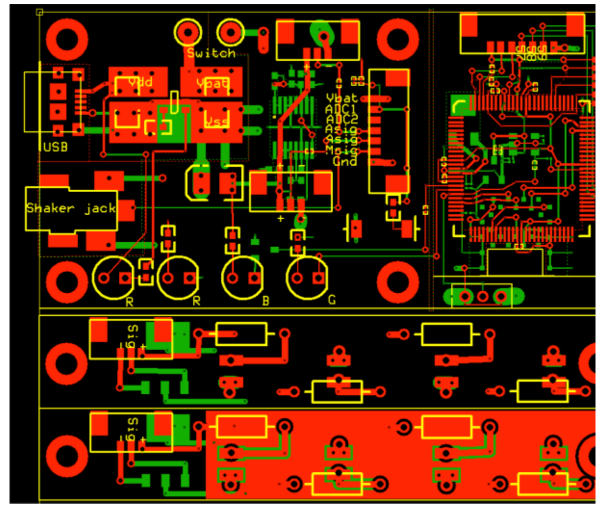

Fig. 13.16. Printed Circuit Board Layout.

MCU and Bluetooth chip were kept to the far right of the board for purposes of keeping the antenna away from as much electronics as possible, to reduce noise and crosstalk. A secondary reason for keeping the Bluetooth to that side is that the customer wanted to be able to break that section of the board off, and use it for future applications. For this purpose, we included a Molex connector with connections to generic input/output pins on the microcontroller. Extra holes were included for mounting screws. The alert LEDs were on a separate board, connected via Molex. The circuit schematics are shown in Figure 13.15, and the final PCB layout for the main board is shown in Figure 13.16.

Total cost was approximately $121.97

More Information available at http://edge.rit.edu/content/P12036/public/Home

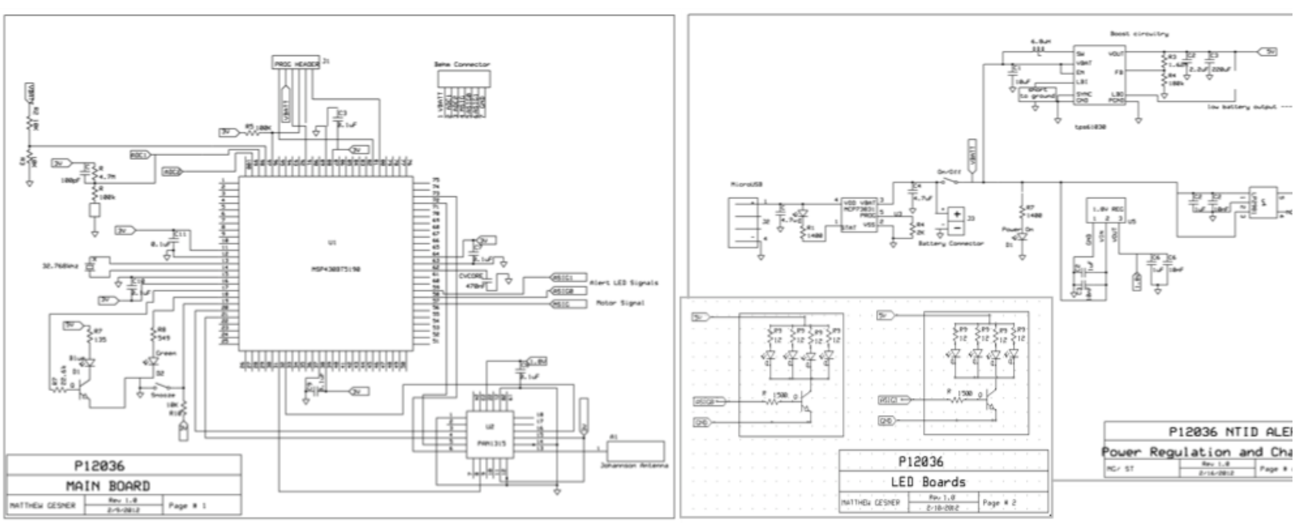

Fig. 13.15. Circuit Schematics (L-R): Main Board, LED Board, and Power Regulation.

DYNAMIC KEYBOARD IV

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Mechanical Engineering Designers: Doug Hemink, David Dallesandro
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Supervising Professor: Prof. George Slack
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INTRODUCTION

The goal of the Dynamic Keyboard IV project is to improve, debug, and partially redesign the existing Dynamic Keyboard (DK) model created by previous groups; with the end goal being a finished product. The Dynamic Keyboard differs from its generic counterpart in versatility and data handling; where normal keyboards only send information about which key is pressed, the DK sends not only the key stroke data, but also the pressure with which the key is pressed and the time associated with the pressure reading. This allows for on-the-fly dynamic text creation, where the font size and other text attributes can be automatically enforced based on changes in typing cadence and pressure. The Dynamic Keyboard targets the deaf community, allowing for enhanced communication through text by way of modifying the font and text characteristics to show emphasis and convey basic emotions.

SUMMARY OF IMPACT

The client had a number of issues with the original DK design, including but not limited to the aesthetics, the "ghosting" problem (keys triggering when not pressed), the tactile feel, and the missing of keystrokes when "pecking" at the keys quickly. The DK IV project sought to eliminate these problems as well as fix other known problems with the previous design (known as phase III). By the end of the project, the keyboard was fully redesigned and functional. The new design satisfied, and in most cases exceeded, the client's expectations. The keyboard had the same physical style as a standard keyboard, felt light and sturdy, detected and utilized pressure and time stamp data when outputting text, and exhibited no "ghosting" effects (Figure 13.17). The DK not only received positive reviews from the client, but also from the public at its first public appearance at the Imagine RIT festival on May 5, 2012.

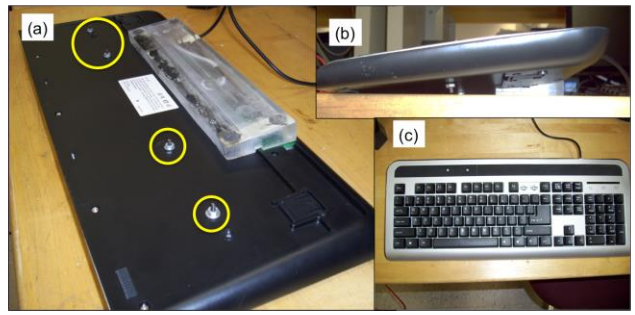

Fig. 13.17. Keyboard Redesign: (a) Metal Mounts and Plexiglas Cover Stabilize Board and Eliminate Ghosting; (b) Side View, and (c) Top View.

TECHNICAL DESCRIPTION

The Phase III design for the DK had a number of major flaws that had to be fixed before more innovative developments could take place. The first issue was the flimsiness of the keyboard case, caused by the Phase III team's Plexiglas wedge backing (Figure 13.17). The board had a tendency to flex when keys were pressed, and due to the unevenness of the wedges, the board sat lopsided when set up. The phase IV recognized these problems, as well as the free floating internal electronics, as the likely sources of the "ghosting", one of the other key problems the team hoped to solve.

The team decided to replace the Plexiglas wedges with a machined metal backing. This made a tremendous difference in the keyboard rigidity and tactile feel, which lead to better pressure readings and eliminated the "ghosting" problem almost entirely. It also increased the aesthetics of the device, making it look much more like a standard keyboard.

After solving the "ghosting" problem the team's next goal was to speed up the system. This lead the Phase IV team to do a total dissection of both the code and the physical model, since a complete understanding of all components was necessary to find any

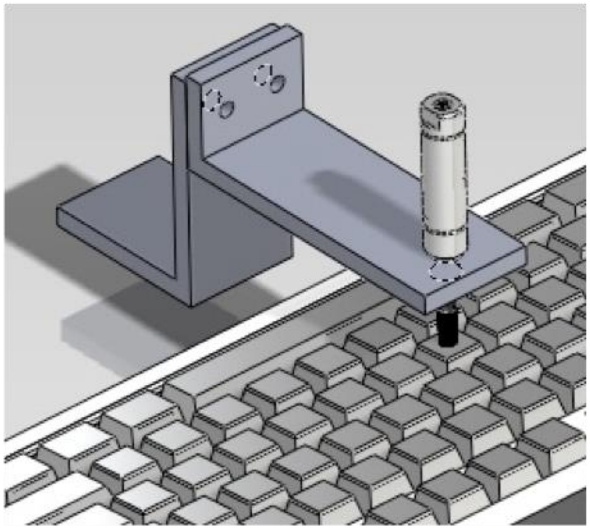

Fig. 13.18. Test Stand: A CAD Model of the Pneumatic Test Stand being used on a Key.

ITEM NO.	PART NUMBER	QTY.
1	Key	1
2	Dome	1
3	Foam (optional)	1
4	Key Sensor Matrix	1
5	Pressure Sensor	1
6	PCB	1
7	Plastic Support	1
8	Metal Baseplate	1

Fig. 13.19. Key Component Diagram: The Different Components Associated with a Key. In the Phase IV Design Components One and Two are glued together, and five and six are soldered together.

problems. One Arduino Nano drove the old DK, which was responsible for handling all data acquisition and processing. The problem with the single processor was that the Arduino Nano could not cycle through the code fast enough to capture “pecking” at the keys. The team had planned to accommodate a second Arduino Nano to share the processing load, but it was found that the code would not work with the two modules working together. The team instead removed erroneous and unnecessary code to get better cycle times and also implemented a test circuit to only relay pressure data above a certain threshold.

With many changes to the old DK taking place, thorough testing had to be done after each modification to ensure that each component still worked properly. The team developed a testing procedure that they followed strictly after each upgrade. If a change had a negative effect on performance or the quality of data, then the team simply reverted back the previous model. Part of the testing procedure included the use of pneumatic test stands (Figure 13.18) capable of exerting a constant force on the keys. With a known applied force, the team could quantify the differences between pressure readings from different sensors. A significant improvement was seen in the agreement of values when the new backing was added, and other small changes to the structure helped stabilize the values.

A final significant improvement in the current design is the use of standard keyboard domes (Figure 13.19). For the current design, the team moved to standard domes that can be removed and replaced, if needed, with commercial, off-the-shelf parts. Overall the team was successful in meeting all goals except the integration of a second Arduino. All engineering specifications and client expectations were met, and additionally a device manual was successfully created.

The total cost for the project was approximately $120.16

More information is available at http://edge.rit.edu/content/P12003/public/Home.

CHAPTER 14
ROSE-HULMAN INSTITUTE OF TECHNOLOGY

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KINDERGARTEN WALKER

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INTRODUCTION

The Kindergarten Walker, shown in Figure 14.1, is designed for a 5-year-old with cerebral palsy, which limits the fine motor control of both of his legs as well as his right arm. The design team developed a collapsible, rear-facing walker equipped with both a foldable seat and a braking system. Since the device will be transported frequently, it was important to ensure that the final design fit easily into the trunk of a standard sedan vehicle. Research suggests that rear-facing walkers, as opposed to more traditional front-facing walkers used primarily by the elderly, promote better posture and reduce the risk of long-term back and hip complications. The design permits adjustability in the height of the handlebars, a necessary requirement for a growing child. Lastly, the parents of the active and energetic 5-year-old expressed the desire for a seat to be incorporated in the final design to relieve them of having to carry him when his arms get tired.

Many assistive walker devices exist on the current market. However, many of the more popular designs are bulky, complex, and unattractive. Our team prioritized developing a design that was sleek and attractive while maximizing function and minimizing input from a caregiver. The complex gearing mechanisms of the device are concealed in aesthetically pleasing housing components. The folding of the handlebars and the legs of the walker is achieved by a simple button push on either side of the walker.

The Kindergarten Walker is a functional, easy-to-use, and cost-effective solution for children seeking assistance in mobility. The design team presented this device to the client with the hopes that it serves him well in the future.

SUMMARY OF IMPACT

The Kindergarten Walker has several features to improve the user's independence in confidently navigating through his surroundings. The

Fig. 14.1. The Kindergarten Walker's (left) Original Rendered Design and (right) Final Design.

Kindergarten Walker incorporates a seat to allow the client to travel further, run faster, and play harder by ensuring that he will always have a resting place directly behind him. The client and his parents no longer need to be fearful of going down a hill too fast due to the incorporation of an easy to use brake system. The walker folds flat to allow for easy storage or transportation. The simple and intuitive adjustability mechanism adapts for changes in the client's height, reducing the discomfort experienced in using an undersized device and the expense of buying replacement devices.

TECHNICAL DESCRIPTION

The Kindergarten Walker has four legs with a support bar between the rear legs. The legs can lock in an open position when in use or in a folded position for storage or transportation. Attached to each leg is a solid rubber wheel that cannot be deflated which allows the user to play on grass and textured surfaces. The front wheels swivel 360°, permitting the user to easily turn the walker. The rear wheels have a braking system to apply a frictional force to slow the walker when the hand lever is squeezed. Both brakes are attached to a single hand lever via brake cables. One hand lever was utilized because the client has limited motor control in his right hand, so the left hand will activate both brakes at the same time.

The walker has a pair of handlebars with a rubber covering to allow the client to easily and comfortably grip the walker. The handlebars also have a slight 20 degree bend to allow for various hand placements while using the walker. The height of the handlebars can increase or decrease in increments of 2 inches to support future growth or posture changes.

A cushioned seat is located behind the user, between the housings that support the handlebars and legs, to allow the client to rest. To use the seat, the client simply needs to rotate the seat. When the client stands, the seat will rotate 90 degrees to the vertical position on its own via an internal torsional spring.

The Fixed Point Rotary Controller is the housing that connects the torsion seat, handlebars, and legs of the walker. It was designed to be aesthetically pleasing and house all metal gears and each button. When each button is pushed, the gears disengage and handlebars can be raised or the entire walker including both legs and handlebars can be moved from a usable to collapsed position, shown in Figure 14.2. Releasing of the button then locks gears into place via a spring, fixing handlebars and legs into a locked position.

The total cost of the walker with all of these features was approximately $420.

Fig. 14.2. The Kindergarten Walker in its Fully Collapsed Position: (left) as Designed and (right) as Built.

FOREARM PROSTHESIS

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INTRODUCTION

The design team's task was to design a lower arm prosthetic (Figure 14.3) for an eight year old boy, who was born with longitudinal deficiency in both the radius and ulna of his right arm. As a result of this disorder, the client has trouble doing simple tasks such as picking up objects of moderate weights with the two fingers he has on his right arm. The client's mother requested that a device be developed for her son which would provide him with the ability to pick up cups and perform other similar actions of which he is currently incapable. It was also requested that the device would be capable of being worn at home, school, and anywhere else they may go.

Various solutions for people with similar conditions already existed, but each design has limitations. A myoelectric device would have allowed the user to control the device without using his fingers, but the cost of a device like this was very high. Another patented device provided a thumb which would enable the user to do things like tying shoes, but this had a method of attachment which the client did not like.

SUMMARY OF IMPACT

The design team focused on a design that would be pleasing to the client and enable him to do more things independently. The prongs of the hand portion of the device are designed to have greater

Fig. 14.3. Forearm Prosthesis as Delivered to the Client.

grip strength than the grip strength of the fingers on the client's right arm. This will certainly allow him to pick up more things, and will also provide him with the ability to hold on to objects more firmly, which was something that he had not been capable of doing in the past.

TECHNICAL DESCRIPTION

This device consists of seven subsystems (harness, casing, electrical components, elbow, hand, linear actuator, user interface) all operating with each other to produce a fully functional prosthesis. The harness was modeled off of a previous design and constructed from the same material as the casing of the device. The elbow and linear actuator subsystems control various aspects of the device, based on input from the user interface subsystem – a series of sliding potentiometers which are under the control of the user. The hand subsystem consists of two prongs (one mobile and one stationary) that allows the user to both grasp or pinch objects, as well as hook them and pick them up, if desired. The organization of each subsystem is illustrated in Figure 14.4.

The design required a few modification from the planned design. The most noticeable and valuable of these changes was the incorporation of wrist rotation into the final device. This was done to ensure functionality for the client. To assure that all of the components of the device functioned as desired, tests were developed and performed throughout the process of the device's creation. These plans reaffirmed the team's belief that this device would be more than useful, safe and appealing to the client and his family.

The total cost to build the prototype was $780, including all supplies and manufacturing costs.

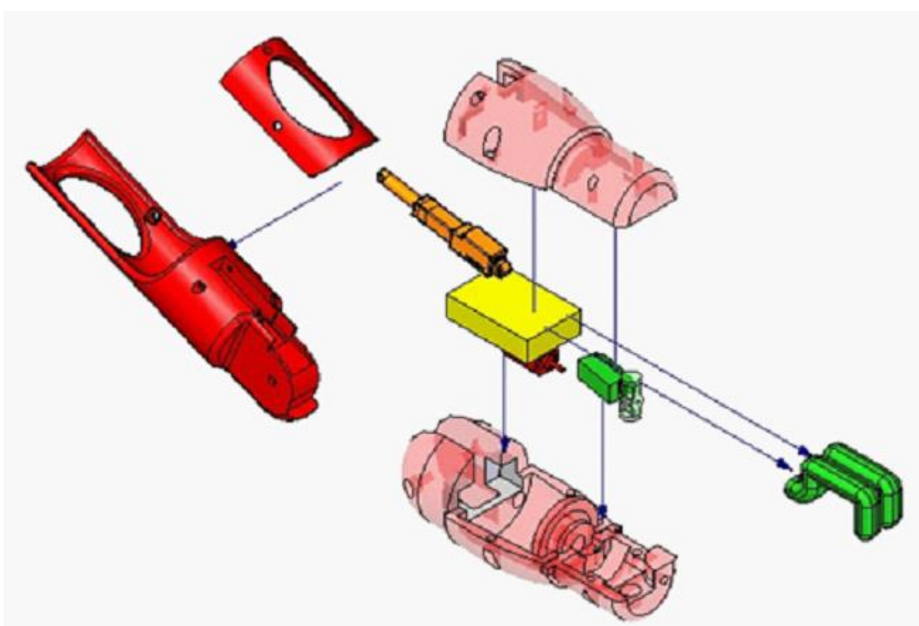

Figure 14.4. Exploded View of the Final Device.

iTALK

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INTRODUCTION

The client for this device has Wernicke's aphasia, which causes them to inject random or unrelated words into their conversation as they speak. Individuals with Wernicke's aphasia are able to understand the speech of others, but find it difficult to be understood. They are often aware of their condition, and become easily frustrated with themselves. This speech barrier makes it very difficult for them to enjoy a normal lifestyle, such as talking to family members or friends. The client's condition has caused many of her neighbors to avoid interacting with her. She feels lonely, isolated, and invisible because she is unable to express herself.

There are some communication devices that are currently being used to help people with Wernicke's aphasia. One such device is Lingraphica, which is a handheld, touch screen device that allows a user to select preprogrammed images by clicking them and having the device verbally express the selected image. This has also been used as a therapeutic tool to help people who have trouble communicating and interacting with another individual. But this application is not customizable and the user is confined to what they are able to talk about based on what is already loaded onto Lingraphica. Other plausible solutions to help people with Wernicke's aphasia are very expensive "translation devices" which are calibrated per person, where no device has been produced - only patented. Another solution is flash cards with images on them to help convey the idea pictorially in a conversation. This is a slow method for communication because the user must search through a number of cards to find the image they would like to talk about. Finally, there are several treatments that involve the use of electrodes to help reconnect the Wernicke region with the rest of the brain. Due to her elderly age and current condition, these procedures are not desired by the client.

The solution developed by the design team is a program similar to Lingraphica, where the user would first select and touch a preprogrammed image, then the device would display the image to visually convey the idea the user was trying to verbally communicate. The program also allows for customization. This solution seems simple and efficient enough to allow a user to communicate their ideas in a short time span.

SUMMARY OF IMPACT

The program developed (Figure 14.5) allows the user to select images on a touch screen device and displays that image with a description. The client can customize the program since she is able to take pictures and upload them into the program or she can select an image from a database and attach a personalized description that will be displayed with the image. Her friends and family members can add information to the database, as well.

This solution allows the client to better communicate with an individual by having the program help display the idea while they verbally communicate with another individual. By improving their communication abilities, it will reduce frustration between both parties and allow the client to interact with her neighbors rather than feel isolated. Because it was programmed in iOS and can be uploaded onto any Apple product that has a touch screen, this solution not only helps this specific client, but also other people with communication disorders.

Since this program allows for customization and will be free for the public, it is another plausible solution for people with communication disorders.

TECHNICAL DESCRIPTION

The final design for this application was developed to include three subsystems: Basic Images and Phrases; Editing, Inputting, and Removal of Device Information; and a Favorites Category. The Basic Images and Phrases subsystem has preprogrammed images with descriptions attached, and the user of the device would select one image by using a touch screen device and the device will then display the selected image and play the audio file that's attached to that image. The Inputting and Removal of Device Information subsystem is to allow the user to either take a picture or select a picture already uploaded on the application and then type a description that will be attached to that image and stored for later use. The Editing subsystem will allow the user to edit information previously saved on the device. The Favorites Category subsystem is designed to allow the user to automatically store the most frequently used phrases or images and allow for faster use of the application.

The total cost of this solution was $589. This included the iPad for the client to run the program, and the iPad case that protects it.

Fig. 14.5. The Main Menu of the Application to Aid in Communication Difficulties.

ANKLE FOOT ORTHOSIS: SUPPORT SADDLE

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INTRODUCTION

A new custom ankle foot orthosis for a young child with overpronation in his ankles was designed, tested, and built. Overpronation of the foot occurs when the ankle turns inward and the arches flatten. When this happens, the patient tends to walk on the inner border of the foot instead of distributing the body weight evenly. If left untreated, overpronation of the foot and ankle could result in shin splints, pain, and tendonitis in the legs. It can also affect other parts of the body such as the knees, hips, and back to over compensate for the over pronation

While designing a new device, characteristics such as functionality, cost, and safety were considered to be the most important factors in the design. For the design to be functional, the ankle of the user must be stable and supported at all times, yet must allow for a natural range of motion. In terms of cost, the device needs to decrease the total cost from the current solution and its accessories. The safety of the user is always held paramount and means that the device should not harm the user in any way. A device is required for both the left and right feet to maintain foot and ankle range of motion while providing stability to correct overpronation in the ankles due to a lack of muscle tone and strength.

There are several existing solutions to correcting ankle overpronation in children, such as braces, straps, and orthotics. While some solutions have positive attributes, slight modifications would need to be made to these existing devices to meet the client's needs.

The client's current device is an ankle foot orthosis (AFO). There are many different designs for current AFO's that vary in the general design, material, and degree of correction. The current AFO must be worn with extra wide shoes at all times and is made of a hard plastic material that is hot and uncomfortable. The closed design of the device and the hot plastic contribute to the user's feet becoming sweaty and prone to fungal infections.

Another possible solution to correcting ankle and foot overpronation is through the use of custom orthotics that can be placed inside the shoe. This orthotic is placed in the shoe of the person with overpronation of the ankles and provides arch support in order to realign the ankle and prevent the pain caused from overpronation. This orthotic would not be ideal for a young child, since children's arches do not begin to form until they are older. This orthotic is also prone to high wear from daily use. This wear would decrease the total amount of ankle support and lead to the overpronation of the ankle it was intended to reduce.

One of the final solutions to treating ankle overpronation is through the use of foot straps that wrap around the foot and provide a lift to the arch of the foot. This foot strap is placed around the arch of the foot and provides arch support, which prevents the foot from flattening out and maintains the structure of the arch to prevent overpronation. This would not be ideal for this client because the user is a young child who does not have completely developed arches. Also, this device could slip from its position in active users and not provide the intended arch support.

SUMMARY OF IMPACT

The Support Saddle (Figure 14.6) improved upon the client's current device by using comfortable materials and exposing more of the foot and ankle in an open design, while still providing the necessary support to correctly align the ankles. The safety of the device is upheld by not having any sharp edges or corners, is composed of biocompatible materials, and does not have any dangerous parts. The device is functional, supports the ankle while still allowing a range of motion in all orientations, and the device is also low cost.

In addition, the Support Saddle is comfortable with padded inserts, moisture wicking materials that contact the skin, and a polyester filled transition area that keeps the inserts in place while also cushioning the lower part of the ankle. The device has two Velcro Velstraps® that are adjustable to provide the correct compression for the user. This adjustable feature also allows for the device to be used for multiple shoe sizes for when the user grows. Since the device is made of durable outer materials and sewn using strong machine stitches, it is considered durable and could survive the daily activities of a small child. The Support Saddle is also easy to use. The design is intuitive to attach to an ankle and can be attached quickly if needed. The device does not require extra wide shoes that would limit the user's options and can be worn with a variety of shoe styles.

TECHNICAL DESCRIPTION

The newly built design is called the Support Saddle. This device is constructed to the size and shape of the user's arches, ankles, and lower legs. The Support Saddle is composed of three subsystems that contribute to the improvements made from the current device such as: comfort, durability, ease of use, adjustability, and compatibility with normal width shoes.

The first subsystem is called the outer shell. This section is the main connection point of the other subsystems. The outer shell has an open design that only covers the inner and outer sides of the ankle and lower leg. Within each side of the subsystem are two pockets that are enclosed by zippers. The outside of the pockets are made of a strong, durable material and the inside is a soft, moisture wicking material. There are also two adjustable straps that keep the device positioned and provide compression support.

The second subsystem is the saddle subsystem that supports the arch of the user's foot while also helping to keep the device attached in the correct position. There is an arch support component that is a non-bulky foam and is attached to the outer shell subsystem by an elastic material. The saddle is also covered in a material to wick away moisture from the bottom of the arch.

The third subsystem is the ankle support inserts that sandwich the ankle on the inner and outer sides. These inserts slip into a pocket in the outer shell and are intended to be compressed together by outer shell straps to provide alignment in the ankle. The ankle support inserts are also lined with soft foam to increase comfort, safety, and conformity to the ankle.

The design team had a projected budget of $210. After purchasing necessary materials, the start-up cost for the Support Saddle was $290, which included testing materials and multiple prototypes. With the excess raw materials, the actual unit cost of constructing a pair of child-size Support Saddles is $42 which is similar to the amount spent on a high-end pair of shoes.

Fig. 14.6. A photograph of Front View (left) and Inside View (right) of the SUPPORT SADDLE.

CONFORMING COMFORT

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INTRODUCTION

Hypotonia is a condition involving low muscle tone that can be caused by a variety of factors including trauma, environmental factors, or genetic, muscle, or central nervous system disorders, such as cerebral palsy, muscular dystrophy, and autism. Hypotonia commonly leads to a state of severe slouching of the shoulders known as kyphosis. Since hypotonia is based in the central nervous system, it commonly occurs in conjunction with a condition known as proprioception dysfunction. Proprioception dysfunction is a state in which an individual is not aware of their body positioning in space because the brain does not receive the proper signals.

There are current solutions to both of these conditions, including a variety of bracing solutions, kinesio taping, and compression sleeves; however, none of the current solutions can provide a solution to both conditions simultaneously. The design team considered the methods used by the current solutions to come up with several designs for a solution that addresses both conditions. Considering the needs of the user and goal of the device, Conforming Comfort was selected as the best device to provide correction for both conditions at the same time.

SUMMARY OF IMPACT

Hypotonia, leading to kyphosis, affects almost every aspect of daily life from personal care tasks to posture. It is important to address this in the early stages of life, so that regular development can proceed. It is also important that proprioception dysfunction is addressed early on. When the brain is not receiving signals correctly, the individual experiences difficulties with motor skills and postural stability, which also affects a child's development.

Conforming Comfort provides a comfortable and easy to use solution for these cases. The use of the device does not take additional time out of the user's day, as therapy can. Instead the user can go about their daily activities when the device is in use.

TECHNICAL DESCRIPTION

The Conforming Comfort design (Figure 14.7) is a vest-like device that has two layers which provide solutions to proprioception dysfunction and kyphosis. Each layer was considered as its own subsystem because they each have their own specific function. The inside layer provides proprioception to the user and the outside layer corrects for kyphosis. The following is a detailed analysis of the function of the design and how it is constructed.

The inside layer, providing proprioception, is constructed of an elastic-based material so that it applies compression to the user. This compresses the nerves in the target area, focusing the brain on the alignment of the spine.

The second layer of the device corrects kyphosis by applying a force to pull the shoulders back. This outside fabric has some flexibility for comfort but is not as flexible as the inside layer so that it can support the force of the straps. The straps are sewn on and extend from below the collar bone to below the shoulder blades, crossing in the back. On each strap is an adjustable buckle to be tightened or loosened based on the size of the child and the severity of the kyphosis. This adjustability also allows for changes as progress is made in posture.

The inside and outside layers are connected by Velcro on one side and sewn together on the other side, near the zipper. There are two half zippers that the caretaker can choose from when placing the device on the child, as well as two Velcro attachments for adjustability of the inside layer. These features accommodate for growth of the child as well as amount of compression applied.

The total cost of producing the final device was approximately $40.

Fig. 14.7. Conforming Comfort Bracing Device that Corrects Kyphosis and Proprioception in Children Ages 3-5.

MEDICATION ASSISTANCE DEVICES

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INTRODUCTION

Actively managing and organizing medications is a vital part of the daily routine of many elderly people, as they are estimated to take multiple prescription medications every day. Reading the fine print on medication containers and distinguishing between medications with similar sizes, colors, and shapes become challenging tasks due to age-related vision changes that are also common in many of these individuals. Maintaining independence also becomes a challenge as they begin relying on health care workers and family members to manage and organize their medications to avoid incorrect medication consumption. Medication assistance devices designed to assist those with visual impairments are valuable tools that ease medication identification. Users remain self-sufficient, and more importantly, reduce the risk of taking the wrong medication.

Existing solutions can be categorized in three broad areas: (1) fine print reading aids, (2) attachments to medication bottles with recording capabilities, and (3) organizational containers. Despite the magnification and backlighting on fine print reading aids, devices that require the user to identify medications with visual cues are not ideal and limit the range of users that can use the device, thus failing to be a holistic solution. The attachments to medication bottles are often bulky or have user interfaces that are difficult to operate for the intended audience. Organization containers either offer too small a storage space or exceed a reasonable size for transportation when accommodating more than a few days' worth of medication storage.

SUMMARY OF IMPACT

The design team has developed two medication assistance devices—Bottle Watch and Medication Box—that realize user needs and address the shortcomings of current solutions. Bottle Watch, shown in Figure 14.8, is a device that eliminates the need for the user to read the fine print on a medication container and aids the user in identifying prescription medication. The device attaches onto a medication container with straps that grip and conform to the shape of the container, accommodating a variety of shapes and sizes. The electronics are designed to allow the user to create a 40 second recordings that can be saved and played back. Holding down the recording button on the surface of the device, the user speaks into a microphone to create a recording about the medication, such as name, dosage, and intake time. Pressing another button plays the recording back, which frees the user from having to read fine print when identifying the contents of a medication container. The device can also attach to objects other than medication containers, such as household items. This method allows users with visual impairments to accurately organize medications without using visual cues through utilizing audio output.

Medication Box, shown in Figure 14.8, is a comprehensive medication organization device that combines a traditional pill organizer with an electronic recording station and an alarm system to remind the user to take medications at specific times. The pill organizer includes five rows of seven compartments that help the user manage a month's worth of medications. The recording station, which functions similarly to Bottle Watch, enables the user to save information about their medications, which reduces the risk of forgetting instructions related to medication intake. For users that have trouble remembering when to take medications, the alarm system is easily programmable to set times that medications must be taken. The alarm system provides audio feedback, where a buzzer goes off at the set time, and visual feedback, where a light turns on when the alarm sounds and turns off when the user presses a button to indicate that the medication has been taken. Medication Box's use of the traditional pill organizer, enhanced with recording and alarm capabilities, assists the user in achieving self-reliance in medication management and lessening medication intake errors.

TECHNICAL DESCRIPTION

The main purpose of Bottle Watch is to function as a recorder and to provide a simple user interface that an individual with visual impairments can easily manipulate. Critical components of the circuit include an integrated circuit system known as ChipCorder®1600B, an oscillating resistor that determines the length of the recording, speaker, microphone, and buttons on the user interface. The interior electronics require a 1.2″ diameter printed circuit board, where Cadsoft Eagle Software is used create the circuit layout. The casing for the electronics is a silicone "slap-watch" casing purchased from a commercial retailer.

The Medication Box is a device that organizes medication, reminds users to take their medication with an alarm, and provides the user the ability to record messages about their medication. The casing of the Medication Box is made out of FDA-approved black ABS. The casing includes slots where the user can store up to a month's worth of medication. Medication Box is compact and light enough to be easily carried and stored. The shelves of the medication box are removable and allow for easy access for cleaning the bottom of the box. Two circuit subsystems are integrated into the Medication Box casing, which include an alarm circuit and a recording circuit. The function of the alarm circuit is to provide the user with an easily programmable interface with color-coded buttons for setting the time and alarms. Key elements in the alarm circuit are control buttons, a microcontroller, a real time clock and accompanying crystal, transistors, and a 4-digit 7-segment display. Two recording circuits, which function identically to the Bottle Watch electronics, are also included and allow the user to record information about their medications.

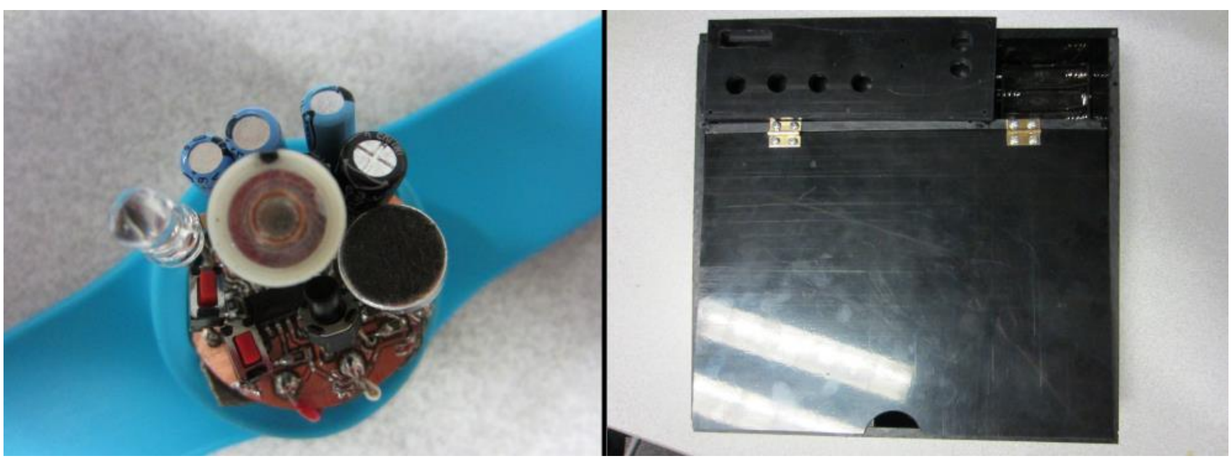

Fig. 14.8. Medication assistance devices: (left) Bottle Watch and (right) Medication Box.

THE MOBIKART

Designers: Brad Foulke, Darius Samz, Andrew West
Supervising Professors: Dr. Kay C Dee and Dr. Glen Livesay
Rose-Hulman Institute of Technology
Department of Applied Biology & Biomedical Engineering
Terre Haute, IN 47803

INTRODUCTION

Youth in Motion (YiM) designed a device for a four-year-old girl who has no use of her legs but would like to play outdoors with her friends and family. The device, called the MobiKart, allows the user to navigate the rough and hilly terrain in her backyard while remaining comfortable and safe (Figure 14.9).

The design focused on durability, effectiveness, and affordability for each of the three subsystems: frame, controls and wheels, and the seat and user interface.

SUMMARY OF IMPACT

The MobiKart addresses the needs of people who enjoy the outdoors but are unable to use their legs to navigate. The device can be used by people of all ages, as it is easily controlled with the user's hands by a joystick. It is much more durable and stable on rough terrain than an indoor powered wheelchair would be and allows users to join friends in participating in outdoor activities while maintaining safety.

TECHNICAL DESCRIPTION

The frame subsystem was made using a pre-assembled steel tubing go-kart frame and two additional steel plates for holding the chair and batteries and electrical components. The steel is strong and durable enough to hold the user and accessories while still being able to endure outdoor terrain. The frame also allows for future modifications to the device.

The control and wheels subsystem has two motors powered by two 12V deep cycle batteries. The front wheels are casters, made to swivel as the wheelchair turns, and the rear wheels are independently driven by one motor each. This setup allows for a zero degree turn radius and the forward speed is limited to about 3 miles per hour for optimal control. The wheels also lock when they are not being driven in a certain direction so that the wheelchair does not roll unexpectedly. The battery life of the device is over 1.5 hours, so the user will be able to use the device for an extended period of time.

The seat and user interface consist of a lawnmower chair and a joystick. The lawnmower chair is larger enough for the user to rest her head on the back, and it is padded for comfort. The joystick allows the user to set different speeds and turn in any direction. The joystick also had a horn in case of emergencies.

Initially, the device was going to use tank treads instead of wheels, but, after further research, using wheels turned out to be a more economical and effective means for transportation. Other design changes included lowering the chair to prevent tipping and including straps in the chair for additional safety. The go-kart frame was adopted not only because it lowered the center of gravity of the device but also because it was a more cost effective way of ensuring a structurally sound frame.

The MobiKart was constructed for approximately $830.

Fig. 14.9. Final MobiKart Device.

KEYLESS ENTRY

Designers: Camilla Beddow, Ethan Nash, Ben Parker
Supervising Professors: Dr. Kay C Dee and Dr. Glen Livesay
Rose-Hulman Institute of Technology
Department of Applied Biology & Biomedical Engineering
Terre Haute, IN 47803

INTRODUCTION

One challenge faced by many students with disabilities at Terre Haute West Vigo Middle and High School is the ability to independently manipulate combination locks and then lift a latch to open their lockers. Approximately 15% of students with disabilities are requesting a device to help them gain locker independence. This demand is due to symptoms associated with various conditions such as spina bifida, cerebral palsy, arthritis, and muscular dystrophy which results in lack of coordination, strength, and fine motor control. As a middle school or high school student, using a locker is a significant part of their daily routine. All of their personal belongings and school supplies are kept in the locker and need to be accessed multiple times during the day. Difficulties with operating the locker not only cause frustration but also hinder the ability to retrieve objects from the locker during the limited time frame allowed during passing periods between classes.

The client for this project is a Special Education teacher who works with students with disabilities, some of whom are requesting a device to gain locker independence. Currently, these students use a key to unlock their lockers, which is attached to a necklace. Next they must push up on a latch to open the door. Unfortunately, this solution is still difficult for some individuals due to coordination and fine motor skill limitations. Furthermore, many keys are often misplaced or lost throughout the school year.

The design requirements for the final prototype included the ability for the device to unlock the locker door, the ability for the device to be used by individuals with limited fine motor control, and the offering of adequate security. Other design considerations included ease of operation, access speed, cost, aesthetics, and removability.

SUMMARY OF IMPACT

The implementation of the Keyless Entry design (Figure 14.10) improves the quality of life for an individual with coordination, strength, and fine motor control disabilities when accessing their locker. This design successfully unlocks the locker with the push of a large, raised button on a wireless remote control. The remote is carried by the user so that they are less likely to forget or misplace it. Once the button is pushed, the device completes the rest of the locker

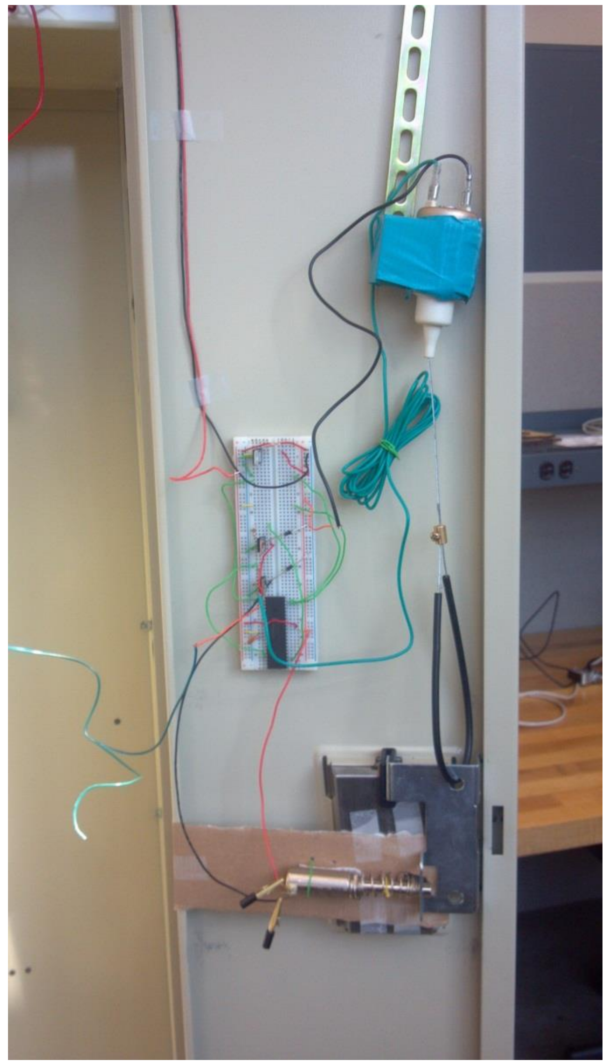

Fig. 14.10. Inside View of the Locker for the KEYLESS ENTRY PROTOTYPE.

entry process by opening the locker door for the user. This functionality removes the limitations of strength, coordination, and fine motor control from locker access. The remote also provides security for the individual since the wireless signal is unique to the remote. An emergency entry procedure was established for teacher and custodian access. Furthermore, the Keyless Entry design only requires modifications to the interior of the locker and therefore appears identical to the other lockers on the outside surface. The design is extremely easy to operate since the individual is only required to press a button and the device can be relocated by a custodian or a teacher with little effort following the instructions in the user's guide.

TECHNICAL DESCRIPTION

The Keyless Entry design consists of four subsystems: the signal and sensor subsystem, programming and power subsystem, mechanical subsystem, and the casing subsystem. The signal and sensor subsystem consists of a wireless remote that gives a signal to the sensor transducer located inside of the locker. This sensor is powered through the next subsystem, the programming and power subsystem. The 12V battery (located inside of the locker) is the first component of the programming and power subsystem, which provides power to the entire Keyless Entry design. Once the sensor receives a signal, it produces an output to the PIC18F4520 microcontroller, which is the second component of the subsystem (Figure 14.11). The microcontroller is programmed to recognize the input from the sensor and send out two timed outputs to both a linear actuator and a pull solenoid. Both the actuator and solenoid are a part of the third subsystem, the mechanical subsystem. The linear actuator acts as the locking mechanism for the locker and the pull solenoid lifts the latch. The microcontroller first sends an output to the actuator, unlocking the door. This signal is then quickly followed by the second signal to the pull solenoid, resulting in the lifting of the latch. Next, the solenoid and the actuator release back to their starting position after the individual has opened the locker. The fourth subsystem is the casing which is used to attach the entire assembly to the locker door. The solenoid, actuator, and breadboard are all connected to the casing and then the casing is hooked onto the interior of the locker door.

The Keyless Entry design met the needs of the client with a final cost of approximately $360.

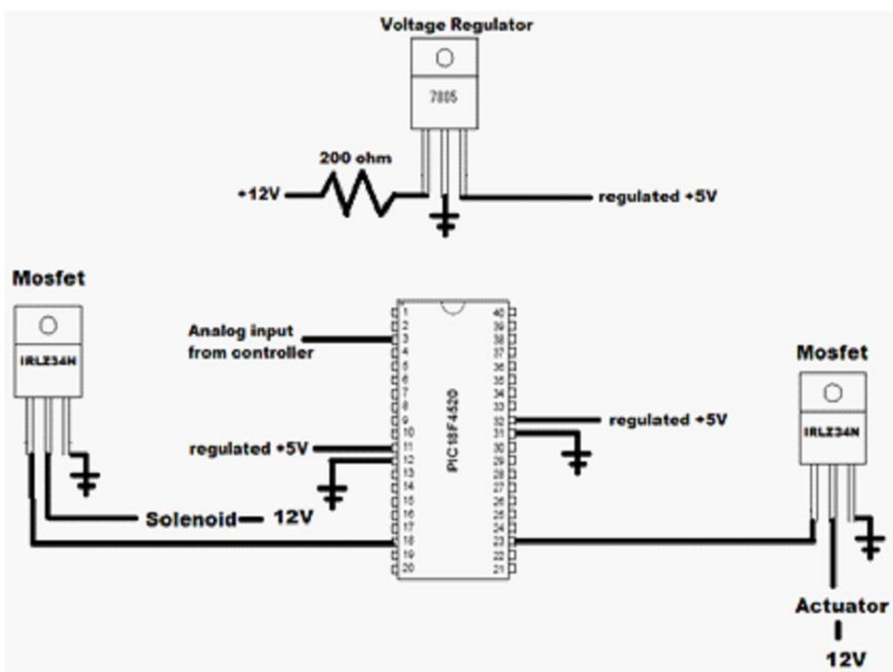

Fig. 14.11. Schematic Illustrating the Device's Electrical Connections.

CHAPTER 15
STATE UNIVERSITY OF NEW YORK AT STONY BROOK

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ASSISTIVE RECUMBENT TRICYCLE (A.R.T.)

Designers: Aaron Dorsey, Harrison Greene and Andrew Mann
Supervising Professor: Dr. Qiaode Jeffrey Ge
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INTRODUCTION

The assistive recumbent tricycle serves as a replacement for a traditional tricycle in the life of an individual with an upper appendage disability. This product is capable of serving multiple functions for the user; as a means of transportation, rehabilitation and socialization with others. Currently, if a handicapped person wishes to participate in cycling, they must pay for an expensive custom-made prosthetic or have a customized tricycle made for them. These options are not widely accessible and can be prohibitively expensive. Our approach was to develop a general solution that can be easily applied to each user in an inexpensive manner. To do this we designed a modification for a user with an upper appendage handicap that prohibits any use of ones arms and hands. This design innovation leads to the placement of the paddles on the user's rips to allow for any disability to be accommodated. The adjustability of the original tricycle combined with an adjustable version of our steering system would effortlessly allow for any adult-sized customer to use our product.

SUMMARY OF IMPACT

The assistive recumbent tricycle brings dramatic change to the users' lives. The users are provided with a new means of independent transportation allowing them new freedom of motion and a means to enjoy the pleasures of cycling in an outdoor environment. They are given a new fun option for rehabilitation allowing them to gradually build muscles and improve cardiovascular health. Finally and perhaps most importantly the users are provided with a means of socializing and participating in cycling events with friends and families which previously was completely beyond their reach. These benefits together provide the users with a happier and healthier lifestyle.

TECHNICAL DESCRIPTION

The implementation of our hands-free steering system was kept as simple as possible. The user leans to the left or right in the direction he/she wishes to turn. By leaning, the user pushes one of the two steering paddles to the side. As the paddles move, the front steering linkage turns the wheels. When the user wishes to exit the turn, he/she simply leans back against the opposite paddle and straightens the wheels. To stop the tricycle, the user removes the feet from the drive pedals and places them on the brake pedals.

Fig. 15.1. Prototype of Assistive Recumbent Tricycle.

The details of the steering system can be easily described in following systems. The rear paddle assembly subsystem acquires the user's input motion and drives the rest of the steering system. The paddle assembly consists of two vertical paddles that are part of a parallel four-bar mechanism. This forces both paddles to move identically regardless of the turn direction. As the user leans to one side, the opposite side paddle follows, this causes the connecting cable to relax on the lean side while pulling on the opposite side. This connecting cable transfers the motion to the second half of the steering system, the front linkage.

The front linkage is comprised of two mirror-image four-bar mechanisms. As the connecting cable is pulled by the paddles, the front pulley turns. As the front pulley turns, the motion is transferred through the linkage to the wheels, causing the tricycle to turn. To exit a turn, the user leans in the opposite direction. The tension of the connecting cable switches sides and turns the front pulley back toward the neutral position, returning the wheels to the forward facing position.

The braking system is made up of the original tricycle's disk brakes with modified brake lever and mounting system. Each wheel has its own independent brake system allowing for slight turning adjustments to be made using the brakes. The user simply moves their feet from the driver pedals to the L-shaped brake pedal and presses downward. This motion rotates the brake lever which in turn pulls the brake cable to activate the brakes.

The cost of the parts and supplies for this project was about $975.

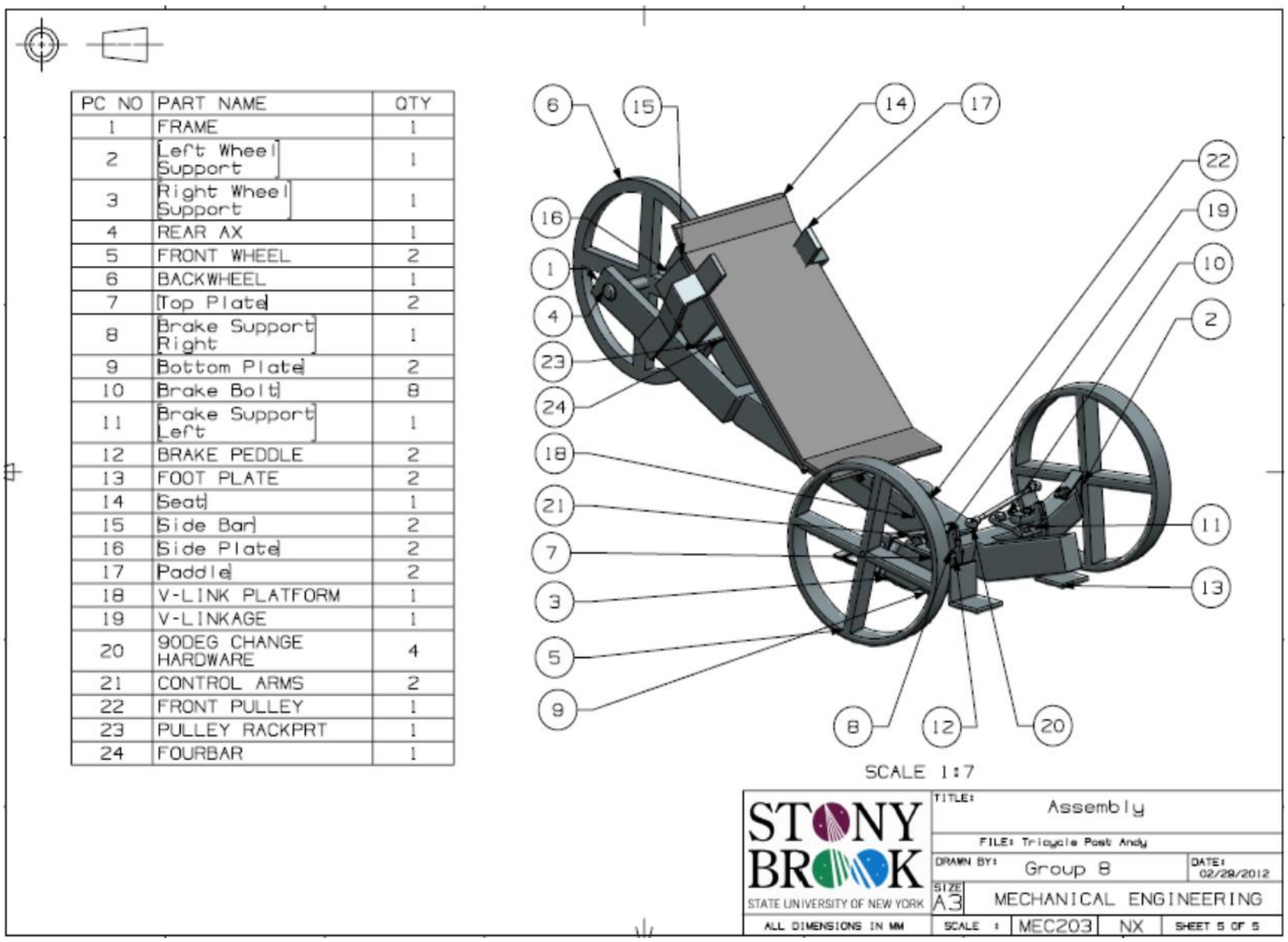

Fig. 15.2. CAD Drawing of the Assembly of Assistive Recumbent Tricycle.

ASSISTIVE LIFTING DEVICE

Designers: Wei Long Qiu, Bibbin Abraham, Louis Ceja and Yue Jun Li
Supervising Professor: Dr. Anurag Purwar
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

An assistive lifting device was designed and prototyped to assist people with sitting and standing. This device can safely lift the user on a desirable path of motion and stabilize the body during operation, and function like a walker. It can help people with back problems, leg problems or other lower body impairments to simplify the process of mobility.

SUMMARY OF IMPACT

Called Assistive Lifting Device, this device serves a purpose that is to help people with disabilities to stand and sit safely. The device can reduce the strain in the back and legs when the user wants to sit or stand. After lifting the user to the walking pose, it provides the support during the walking process similar to a medical walker. The device provides a powerful mobility device to the targeted users, and enhances their independence in daily activities.

TECHNICAL DESCRIPTION

One main challenge to the design is to enhance the stability of the walker. When a person is being lifted or seated by the walker, there is a tendency to flip backward due to the position of the user's center of gravity. As a solution, we added an extension leg to the design. During the operation of the device, the extension leg will create the counterforce to the weight of the user and increase the stability. Since the objective of our device is to compensate for a sofa of 28″ width and to allow fitting through a standard door of 29″ width, we need to design the extension leg to expand and contract at different uses. When the user is being seated or lifted, the device will be expanded to its maximum footprint. When the user uses the device as a walker, the width of the device needs to be less than 29″. The solution to this problem is to create an extension leg that will translate and rotate. The rotational motion will expand the leg to the two sides and increase the overall width, and the translational motion will push the leg behind the user to create counter reaction force. The extension leg is powered by a linear actuator which provides the translation motion. The extension leg can be retracted to the most compact size by going against a cam profile wheel. A fin is attached to the rotational leg, and it will go against the wheel and rotate downwards. The actuator will also be used to move a knee pad for the user to push again in the lifting process. The knee pad will stabilize the body during the operation of the device.

Fig. 15.3. Prototype of Assistive Lifting Device.

The device consists of 1″ aluminum square tubing frame with 1/8 wall thickness. The two actuators on the sides are used to power the six bar mechanism and also will lift the user from the arm rest. The middle actuator is used to power the extension leg and also the motion of the knee pad. The battery and the actuators are all connected to a controller box. There are four 5″ wheels that are mounted at the bottom of the frame to support. The device also provides an easy interface for the user to operate.

The cost of the parts and supplies for this project was about $1500.

PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	6 Bar Ground
2	4	Telescopic
3	2	Track
4	1	Frame
5	1	actuator fixture
6	1	track
7	1	Track connect
8	1	Actuator (la29)
9	2	Inner Tube
10	2	Outer Tube
11	1	Track Threaded middle rod
12	2	Track bracket
13	1	Knee Pad
14	1	Battery 918500
15	1	Controller Box 06
16	6	Wheel assembly
17	2	6bar assenly
18	2	Linear Actuator (La 31)
19	3	Arm Rest

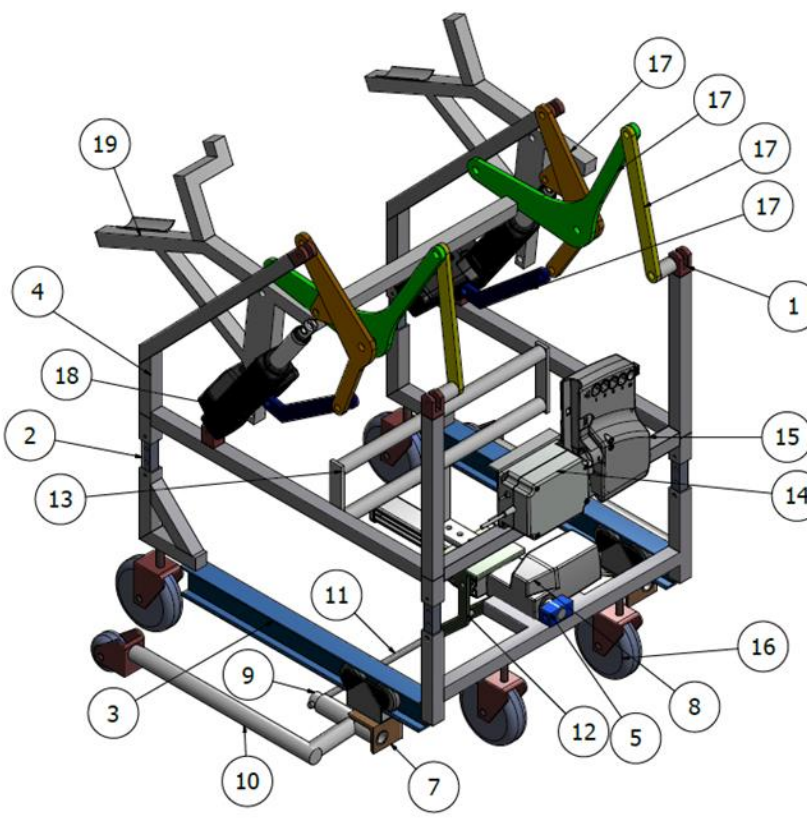

Fig. 15.4. CAD Drawing of the Assembly of Assistive Lifting Device.

HUMAN POSE IMAGING AS A CONTROL METHOD FOR ROBOTIC ASSISTIVE TECHNOLOGIES

Designers: Richard Anger, Taurean Dyer, Anthony Hannigan and David Umlas
Supervising Professor: Dr. Yu Zhou
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INTRODUCTION

The objective of this project is to develop a simple and intuitive control interface for robotic and tele-operated assistive devices that can be easily embedded into existing and future devices. While the potential for future assistive technology is great, the complexity of control interfaces is a hindrance to the technology's applicability and marketability. The deployment of complicated assistive devices, such as a robot, could be facilitated by a significant improvement in the simplification of the control interfaces. This design employs the user's human arm movement to control a mobile robotic arm.

SUMMARY OF IMPACT

The development of this control system will allow for wider deployment and application of assistive technologies. Our survey shows that senior citizens are severely disinclined towards trying to use complicated control systems, and that significantly more are interested in trying to use an assistive device such as a robotic arm if the control interface does not require using levers or buttons but rather allows you to control by moving your arm. The designed control system will bring simplification in operations, and hopefully make more assistive technologies available to users who would otherwise not consider them due to the control complexity and training limitations. The control system also shows promise for non-assistive applications, such as industrial machine control, robotics, and many other kinematic devices.

TECHNICAL DESCRIPTION

The human positioning system used in the design is the motion capture technology of the Microsoft Kinect™. The Kinect uses structured infrared light to acquire a depth field, which is used to exact a human pose, computing a "skeleton" of coordinates of body parts. This data allows the user to control a robotic arm simply by moving their arm, with the motion of the robotic arm mimicking the motion of the human arm.

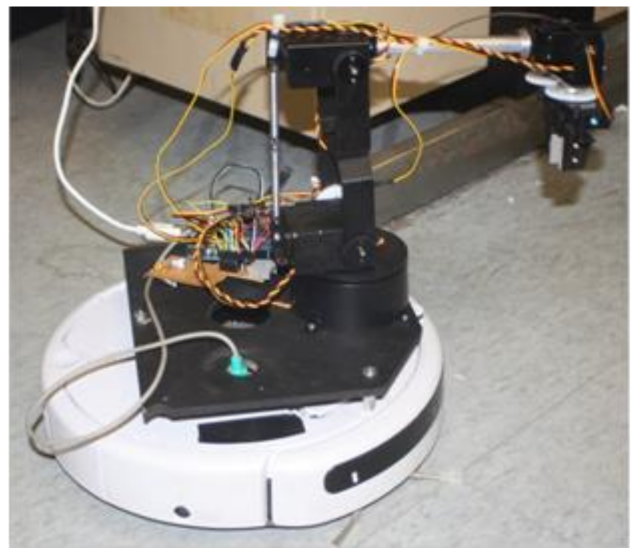

Fig. 15.5. Prototype Testing Platform.

The system can be controlled with a single hand and uses both the motion capture technology employed by the Microsoft Kinect™ and the Wii Nunchuck™. This system gathers data from the structured light based depth map of the Kinect™ and the gyroscope of the Nunchuck™, and uses signal conditioning to extract geometrical coordinates of critical points on the user's arm and body. It then uses a form of inverse kinematics and other algorithms to generate output instructions for a robotic arm. The system also uses the joystick of the Nunchuck™ to allow for simple control of the mobile platform to which the robotic arm is attached. Buttons on the Nunchuck™ allow for further user control of the system's processes.

The system was designed to be robust enough that it can be readily adapted to a wide spectrum of kinematic devices. The control system was designed with intuitive, natural motions, safety, and cost as a prominent feature.

The cost of the parts and supplies for this project was about $1000.

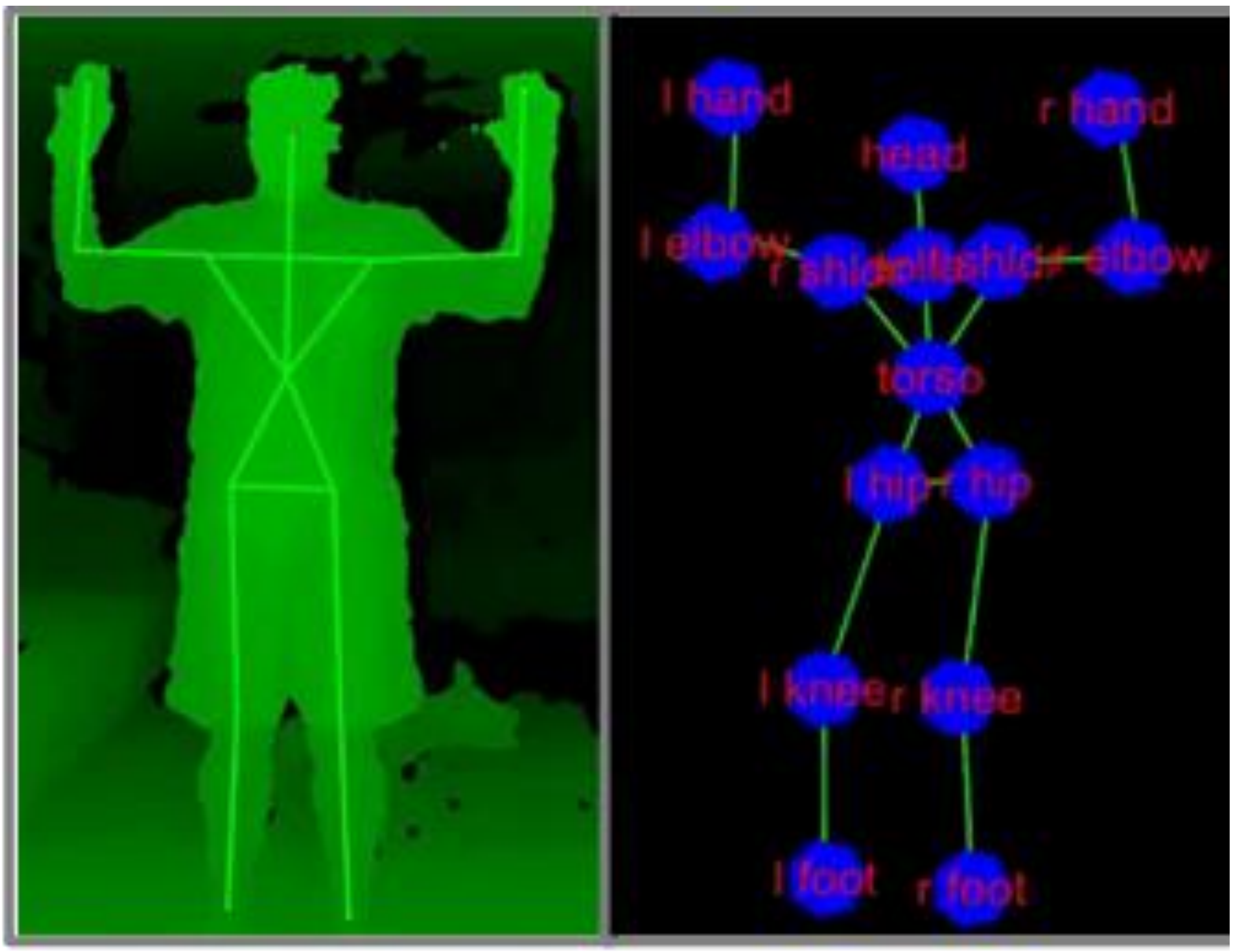

Fig. 15.6. Kinect Motion Capture.

FAST SPEED DRIVING WHEELCHAIR

Designers: Yunchang Lee, Cathy Yu, Jinwoo Park and Donghwan Baek
Supervising Professor: Dr. Yu Zhou
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

The fast driving wheelchair was designed to improve the wheelchairs used daily by people with lower limb disabilities. The design was made by combining the features of a tricycle and a wheelchair. Different from the currently existing designs for tricycles or wheelchairs, the fast driving wheelchair has a translating motion driving system, which would make users feel more comfortable to use. It has a convertible front wheel which can be shortened when the user drives it indoors. It is similar to a regular wheelchair when the front wheel is folded. However, when the user drives it outdoors and needs to ride a long distance, the front wheel can be extended, and the sprocket driving system enables a fast driving speed (up to 14 miles per hour). The fast driving wheelchair has a compact design, and its back can also be folded down. Since both the chair and front wheel are convertible, and they can be closed to reduce the carrying and storage space. It is possible to be carried and stored in a van. Additionally, a shock absorbing system was included in the design to ensure that the fast driving wheelchair has a strong anti-vibration ability. It has no problem overcoming any small obstructions on the road when it is under a high speed driving. In addition, the brake system helps the wheelchair stop quickly.

SUMMARY OF IMPACT

The statistics shows that 4.6% of the U.S. population has lower limb disabilities or impairments. These people rely on their wheelchairs for most of their daily activities. The current existing manual wheelchairs move slowly and require high effort from the users to drive and control, while electrical-driven wheelchairs are expensive. The design of the

Fig. 15.7. (Left) Prototype of Fast Speed Driving Wheelchair (Extended). Fig. 15.8. (Right) Prototype of Fast Speed Driving Wheelchair (Folded).

fast driving manual wheelchair provides an improved option to the wheelchair users, helping them move fast with low cost and improving their life quality.

TECHNICAL DESCRIPTION

With the fast driving wheelchair, the user pushes and pulls the hand bars to convert the arm power to mechanical power, which is more comfortable and requires less effort than directly rotating the rear wheels by hand. The compact size of the design ensures that the wheelchair can enter any daily used space and provide more convenience.

The front wheel can be extended to make the whole wheelchair more stable when it is driven in a high speed on the road. The shock absorbing system increases the ability to overcome bumps and small obstructions that often occur on the road.

The driving system consists of a 3-piece sprocket set, a 5-piece sprocket set and a chain. The 3-piece set was connected to the hand bar to convert human power to mechanical power and rotate the sprocket systems. The 5-piece set was installed on the shaft of the rear wheel to rotate the wheel.

The front wheel, rear wheels and chair were connected by a T-shape structure made of ANSI 1020 steel.

The total material cost of the project is about $650.

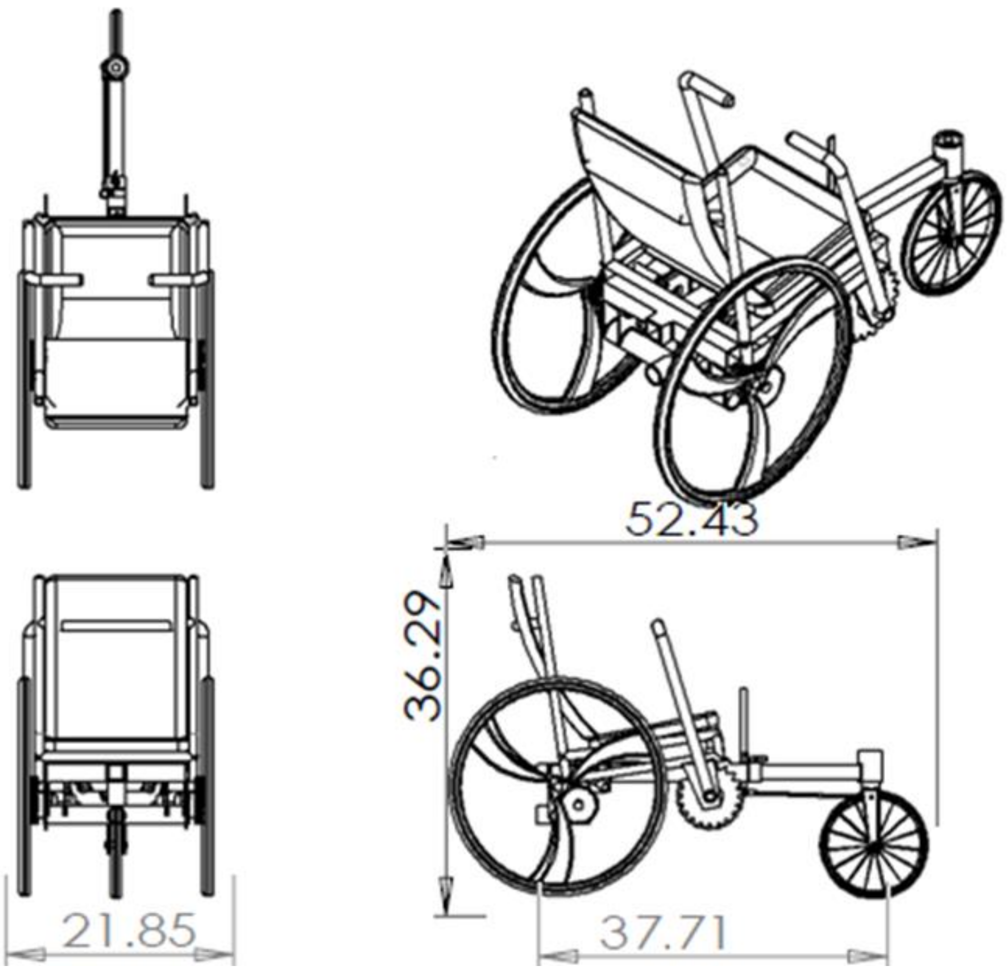

Fig. 15.9. CAD Drawing of the Assembly of Fast Speed Driving Wheelchair.

THE HANDI-GRILL

Designers: Anthony Campos, Stephen Groneman, Justin McNamara and Mahal Patel
Supervising Professors: Dr. Chad Korach
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

An automatic flipping and temperature-controlled grill was designed for two purposes. The primary reason was to assist people that may have trouble in grilling foods due to not being able to stand for extended periods of time, being sensitive to smoke, or even having wrist or elbow injuries that make grilling difficult or painful. The secondary reason was to provide a product for people that do not know how to grill or feel that it is a waste of time. A normal grill requires relatively consistent attention from the user to produce quality cooked food. This requires being able to stand outside for extended periods of time around smoke, dexterity to the flip food and a working knowledge of the grilling process. If any of these abilities are lacking, a normal grill is just not sufficient. Our solution to this problem was to create a grill that can be programmed to cook your food properly without any supervision. The user can now place the food on the grill, touch a few words on a screen, and then just come back when the food is done. It eliminates the hassles of supervision and the frustration of poorly cooked food.

SUMMARY OF IMPACT

A normal barbeque grill provides some users with a cooking method that is simple and convenient, and produces flavorful food. Some people, though, have difficulty cooking on a grill due to physical disadvantages or even a lack of know-how. By automating the grilling process, all users will now be able to enjoy the results of cooking on a real grill without all the hassle that normally comes with it. The grill no longer needs constant supervision, which means that the user no longer needs to stand for extended periods of time. The automatic grill also flips the food by itself so people that are sensitive to heat or simply cannot perform the flipping motion for any reason can still enjoy the use of a grill. If the user can flip a switch and press a few words on a screen, then he can grill.

Fig. 15.10. Finished Prototype.

Fig. 15.11. Gas and Flip Control Systems.

Fig. 15.12. Chain Drive for Flipping Mechanism.

TECHANICAL DESCRIPTION

The automatic grill still utilizes many of the parts of a standard grill. The body of the grill and the burners still remain. The fuel source is still a standard propane tank, but that is where the similarities end. The standard low-pressure propane regulator and knob controls have been replaced by a 10psi regulator that is in line with a variable controlled solenoid pressure valve. This allows the gas to be controlled by the Arduino Mega microcontroller. The temperature is monitored by a type-K thermocouple mounted to the grill surface. The microcontroller can then increase or decrease the gas supplied to the burners depending on the temperature setting.

The grill surface itself is a completely customized piece. The grill bars, flipping shafts and main shafts are stainless steel, meeting the food industry regulations and strength and heat resistance. The main frame and other moving parts are made of aluminum due to cost and its ability to act as a heat sink. The shafts are held in place by oil-impregnated bearings. The steel-on-brass fitment greatly reduces the friction on the joints. The main shafts have sprockets attached at the rear of the grill and are flipped by a stepper motor by means of a chain and sprocket. The motor, driven by a power supply through a motor driver, is controlled by the Arduino Mega. The microcontroller is programmed to cook different types of food to different doneness. All of the options are selected on the touch screen. A manual override is available just in case there is a time when automated cooking is not desired.

The cost of the parts and supplies for this project was about $675.

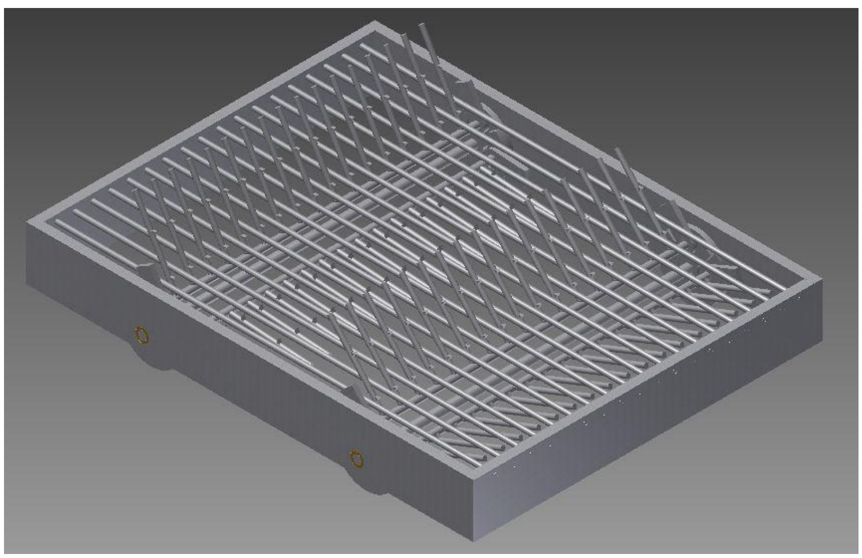

Fig. 15.13. CAD Model of the Grill Assembly.

LAND-SAILING YACHT FOR INDIVIDUAL WITH LOSS OF LOWER EXTREMITY MOTOR CONTROL

Designers: Mark Appledorf, Nicole Himmelwright, Carl MacMahon and Kelly Zorn
Supervising Faculty Professor: Dr. Thomas Cubaud
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

A land-sailing yacht was engineered and fabricated to provide recreational activity for people with loss of lower extremity motor control. Many existing models boast a three-wheeled triangular shaped vehicle that is operated by using hands for the boom and feet for the steering system. These models create a problem for people with such disabilities, because the chair for the vehicle is usually obstructed by the triangular structure and the operation of the vehicle requires the use of feet and legs. The use of three wheels also increases the friction and reduces the efficiency to which the vehicle utilizes the wind. These problems motivated the design of our land-sailing yacht, as it is designed to ride on at most two wheels and eliminates the need for feet to steer the vehicle.

SUMMARY OF IMPACT

Recreational activity can be challenging for individuals who have no lower extremity motor control. This product succeeds in allowing such persons to ride the land-sailing yacht by using only their hands. The boom, used to control the intake of the air, and in turn the speed of the vehicle, can be controlled with one hand via a rope and pulley system, while the other hand can be used to control the steering via a push-pull mechanism. The design allows for easy access to the riding position as it eliminates all barriers to reaching the seat via a wheel chair and contains a swivel and sliding mechanism for the seat to accommodate people of all sizes. The design also allows for reduced friction as it needs to only ride on, at most, two wheels. This makes the vehicle much more efficient with the wind the sail captures.

TECHNICAL DESCRIPTION

The overall system consists of essentially four components attached to the main central chassis, also known as the nugget. The nugget is made of steel square tubing and boasts an arrow shape to which the

Fig. 15.14. Prototype of the Land-Sailing Yacht.

side arms, the front extension arm, the rear extension arm, and the mast are attached. This section is the heaviest but also the strongest, as it takes on the highest stresses within the vehicle and is also the location to which the individual sits. The front and rear extension arms are steel square tubing but of much less weight and smaller cross sectional area. These arms are adjustable depending on the size of the person riding the vehicle and are connected by two bolts. Attached to these extension arms are the front and rear fork and wheels. The front wheel is a bicycle tire obtained from a children's bicycle while the rear wheel is a BMX bicycle tire. The side arms are made of PVC and attach the side wheels to the main nugget. The pneumatic wheels are attached to the PVC side arms via an aluminum adaptor, an aluminum spindle and a steel hub. The mast is connected to the nugget by steel square tubing. The mast which consists of two steel tubes, one fitted inside of the other, is placed inside the steel square tubing until it rests on the nugget and then bolted. Connected to the mast is the boom which operates the sail of the vehicle.

Many of the components were machined from stock materials. Other components, such as the bicycle tires and breaks were bought standard and then usually modified in some way to fit our need for the vehicle. Milling, turning, drilling, cutting and welding are the methods used to modify materials and create the tolerances necessary for this prototype.

Future work on this product will include reducing the weight of the mast along with the rest of the vehicle. It will also include finding a way to strengthen the side arms while maintaining the light weight that PVC offers.

The cost of the parts and supplies for this project was about $700.

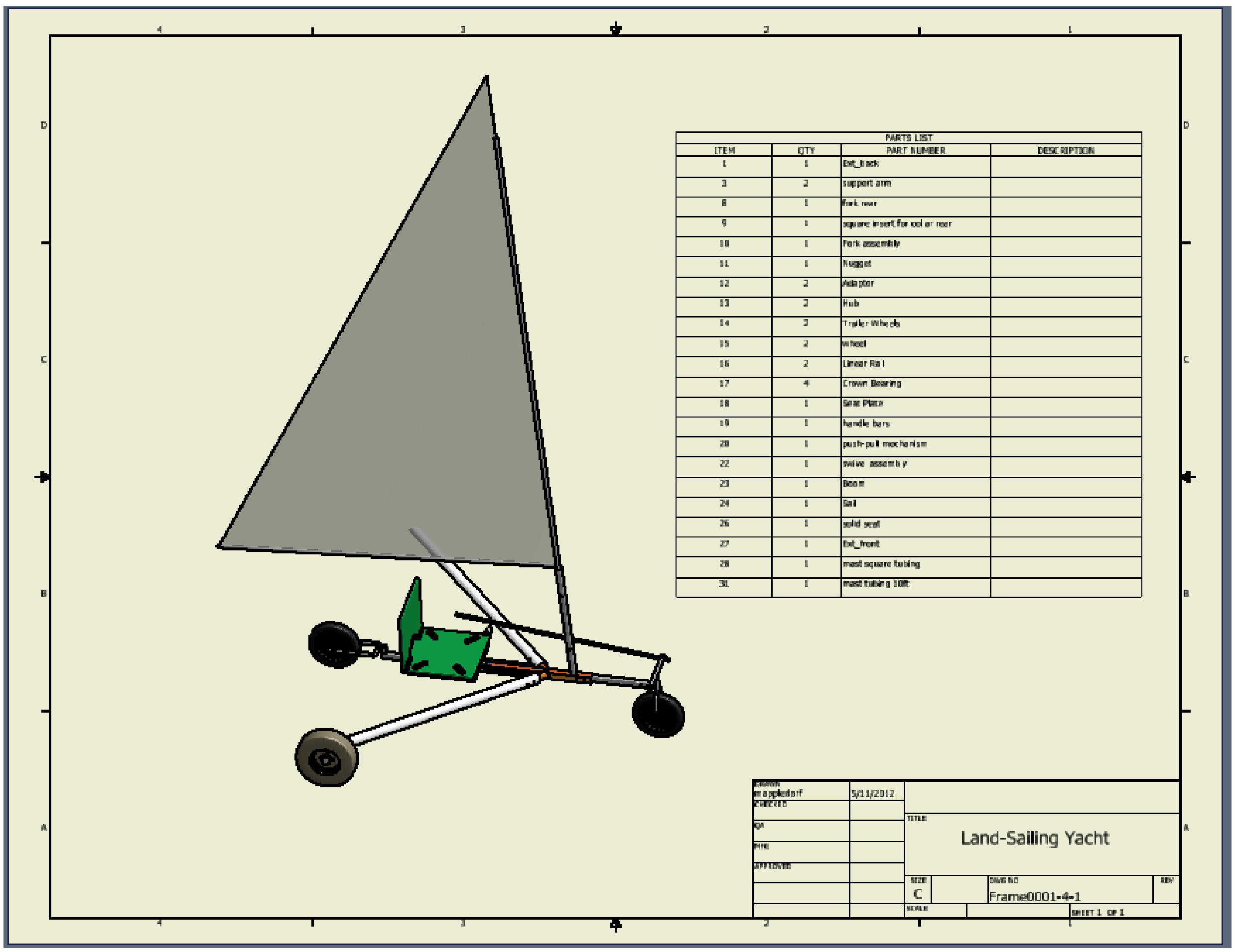

Fig. 15.15. CAD Drawing of the Assembly of the Land-Sailing Yacht.

SLED-BASED FORCE MEASUREMENT SYSTEM FOR FOOTBALL PLAYERS

Designers: Chris Lovasco, George Barbieri, Ildar Khabibrakhmanov and Daryl Trinidad
Supervising Professor: Dr. Yu Zhou and Dr. Sue Ann Sisto
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

The objective of this project is to design a sled-based force measurement system for football players. In the sport of football, a major component of a player's repertoire is his ability to block and tackle an opponent. While devices to test this exist, none is capable of producing a set of quantitative data to be used for rehabilitation progress purposes or general training enrichment. In order to acquire this valuable data, the designed device consists of a stationary football blocking sled outfitted with a series of sensors to capture every linkage's movement throughout the progression of a football player's hit. This data is then compiled and used to generate a force component profile of the user's hit over a predetermined time interval. In order to determine the location and minimal amount of sensors needed to optimize both efficiency and accuracy, a detailed dynamic and kinematic analysis was performed. After optimizing the sensors' locations, the best method of securing the device to minimize vibration while remaining structurally sound was implemented. Using a computer program unique to the device, an operator will be able to analyze all force components of a player's hit to aid in tracking progress during sports rehabilitation as well as for performance optimization.

SUMMARY OF IMPACT

The force-measuring football sled has an impact in the field of rehabilitation study and football performance evaluation. The device will be used in the study of shoulder injuries to understand the force experienced in the shoulder during a block as well as the muscles involved in the block. Utilizing this data, researchers will be able to determine preventative measures and training which focus on the muscles involved in supporting injury prone areas such as the shoulder to prevent further injuries. The device will also be used during rehabilitation of an injured athlete to monitor his strength recovery. For performance evaluation, this device can be used to quantitatively measure a linebacker's potential blocking force. No device on the market currently measures this force, and most athletes and coaches rely on indirect measures of strength and speed that do not necessarily translate into a blocking force. With such a device, linebackers in football can be evaluated qualitatively in terms of their blocking power.

Fig. 15.16. Prototype of the Force Measurement System.

TECHNICAL DESCRIPTION

Using an array of force load cells, accelerometers, and gyroscopes, the modified stationary football sled is capable of reading the impact force of a football player. By modifying the base linkage of the football sled, a custom-made base structure was designed to be able to measure the reaction forces that the linkage undergoes during a user's hit. The designed base structure includes holes on the bottom to be secured to the floor, as well as tabs to allow the force load cells to be secured properly to the device.

The force and motion sensors for this device were chosen carefully to withstand high forces, measure forces both in tension and compression, and use with a standard data acquisition device. Due to the varying technical backgrounds of those using the device, all sensors were chosen to be self-contained to prevent the need for any troubleshooting due to a bad electrical component such as a resistor, capacitor, etc.

To ensure the device's user-friendliness, the program used to acquire all data was designed in LabView, with a front panel that can be operated by people of all technical backgrounds. Shown on this display is a real-time graphical display of each force component and the magnitude of the force. The program saves all acquired data to a file which can then be further analyzed.

The total cost of the parts and supplies for this project was about $6275.

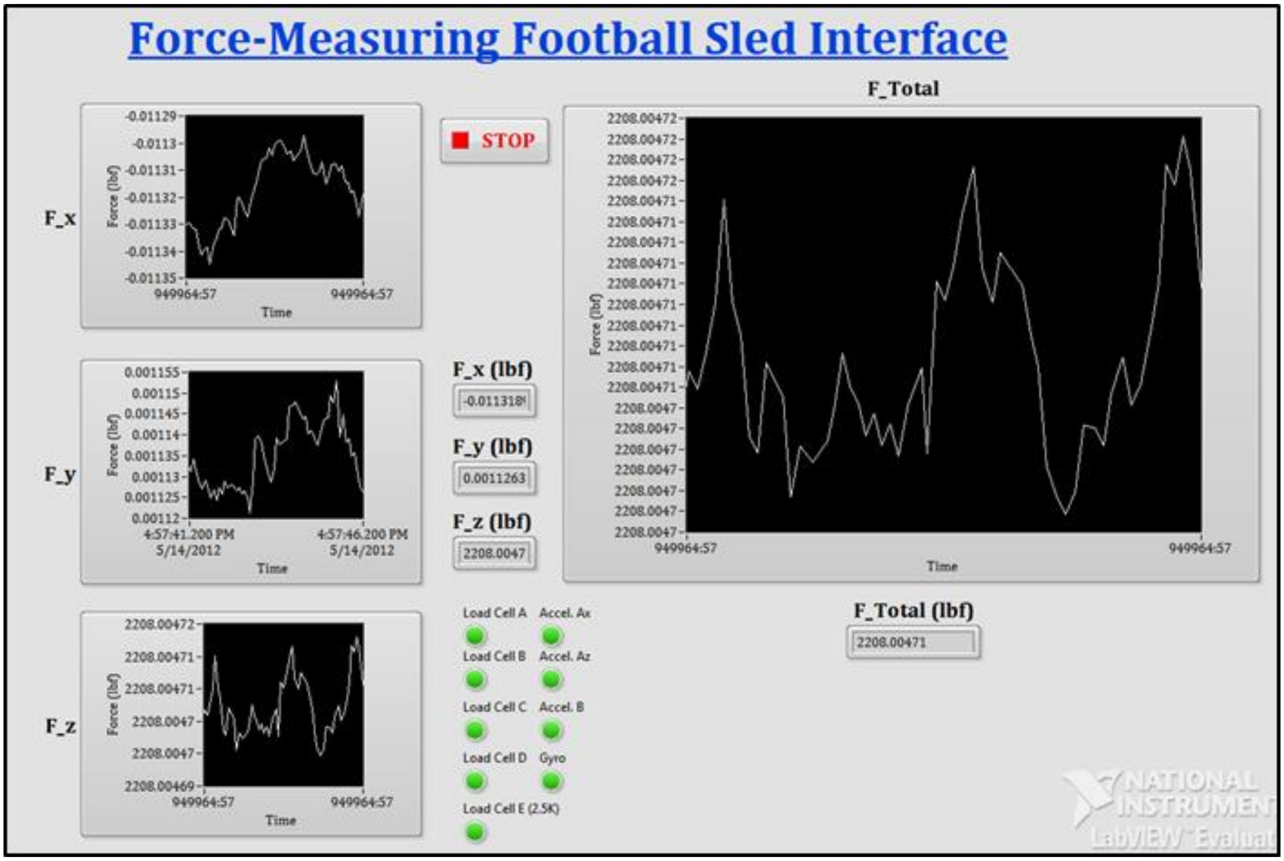

Fig. 15.17. LabView Interface in Use.

THERMOELECTRIC POWERED HEART RATE MONITOR

Designers: Jennifer Maceiko, Joey Russo, Anthony Falesto and Maurice David
Supervising Professor: Dr. Lei Zuo
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

Thermoelectric generating technology is being pioneered today as a future method of generating electric energy by harvesting waste heat of various means. Some examples of waste heat will be body heat, engine exhaust or essentially any heat that is produced by machines. This project focuses on harnessing this waste heat in order to produce enough electric energy to power a heart rate monitor. It operates on the principle that a difference in temperature induced on two sides of a thermoelectric generator will result in a small voltage and current flowing through the circuit. The voltage is small and is boosted using a DC-DC converter in order to create a large enough charge, sustained over a long period of time, in order to charge three AAA Ni-MH batteries. Currently all these heart rate monitors are battery powered, but these batteries need to be frequently replaced. Even if rechargeable batteries are used, these batteries will often have to be charged using an electric wall charger. A technological and societal emphasis is being placed on renewable energy for the continued preservation of our environment. This design eliminates the need to ever charge batteries using a wall charger, and is wearable.

SUMMARY OF IMPACT

The three R's of reducing the carbon footprint have always been stressed as being Reduce, Reuse, Recycle. The key elements of the thermoelectric powered heart rate monitor are to tackle these key points. The device does not require an extra power supply as it utilizes a rechargeable battery in order to store the charge produced by the thermoelectric generators. It is reusable for up to 3 to 5 years; equivalent to hundreds of recharge cycles. The design of this device is small and very light so it is easy to wear on the wrist without looking cumbersome or feeling uncomfortable and will be convenient for the user. The impact of the widespread use of this concept is phenomenal as it has the potential to power, not just a heart rate monitor, but many small household devices.

Fig. 15.18. Prototype of Thermoelectric Generator.

TECHNICAL DESCRIPTION

The thermoelectric generator is a small, one inch square device consisting of 127 Bismuth Telluride thermocouples encased in a ceramic shell. With the 5 degree Celsius difference in temperature between the hot and cold sides of the TEG, 40mV is produced. Four of these thermoelectric generators are connected in series to boost the voltage to 160mV. This voltage is fed into a DC-DC converter which needs a minimum of 80mV to power it and in turn boosts the voltage to 10V. The thermoelectric generators are housed on an aluminum plate which acts as both a place holder and a heat sink. Additional pin fin aluminum heat sinks are placed on top of the thermoelectric generators in order to aid in cooling, ensuring a maximum ?T is maintained. Everything is held in place using thermally conductive epoxy to ensure that maximal heat is transferred from the body to the hot side of the thermoelectric generators.

Three AAA Ni-MH batteries with a voltage capacity of 1.2V and 850mAh are used to store the charge produced by the thermoelectric generators. A diode is placed in series before the batteries to ensure that the voltage flows only one way to the batteries and not from the batteries to the thermoelectric generators. The batteries are in turn connected to the heart rate sensor through two wires which are connected to the positive and negative leads of the sensor circuit. It takes about 50 minutes to charge the batteries to approximately 2.88V at which time the sensor can be activated for a period of 3 minutes of constant monitoring. This discharge time could be increased if the sensor duty cycle was decreased. The sensor takes approximately 10 seconds to give a heart rate reading.

The cost of the parts and supplies for this project was about $300.

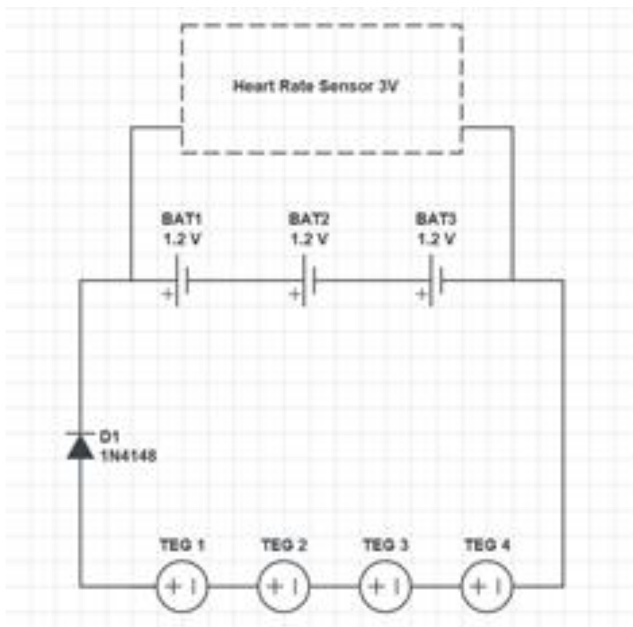

Fig. 15.19. Charging Circuit Diagram.

CHAPTER 16
UNIVERSITY OF ALABAMA AT BIRMINGHAM

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A MOTORIZED WALKER

Designers: Rana M. Atieh, Andrew D. Fox, Charlotte Mae K. Waits
Client Coordinator: Mr. Brian Mueller, CP/LP; UAB Spain Rehabilitation Center
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
Department of Biomedical Engineering
University of Alabama at Birmingham
Birmingham, Alabama 35294

INTRODUCTION

This design provides enabling technology to the UAB Spain Rehabilitation Center by providing a new gait-training device called a motorized walker. This device is used by people with recent lower limb amputations who have been fitted with prosthesis. Specifically, Mr. Brian Mueller, CP/LP will use the device and guide amputees towards proper ambulation. Following amputation, gait is altered forming new center of gravity, making gait-training very important. The goals of gait training are as follows:

- Achieving optimal weight bearing on prosthesis
- Restoring optimal gait pattern
- Teaching amputees how to perform daily operations (standing up, sitting, walking, etc.)

Current devices used for gait training are the standard walker (with or without wheels) and stationary parallel bars. Although the standard walker enables amputees to be mobile, they do not prevent the user from favoring his or her natural leg, and require user effort to push or lift the device with each step. Parallel bars are a great tool for proper posture during ambulation, but are stationary and are only found within the physical therapy center. To circumvent this problem of improper posture with a mobile device, the student team successfully combined the ideas of a standard walker with stationary parallel bars by adding a motor and wheels to an existing walker. Once constructed, the device will be used by amputees during physical therapy at UAB Spain Rehabilitation Center.

SUMMARY OF IMPACT

The Motorized Walker will be used by Brian Mueller CP/LP and the staff at UAB Spain Rehabilitation Center in order to help amputees restore an optimal gait pattern. The aim is to help lower limb amputees quickly adapt to their new appendage, create better posture and continuous ambulation, and decrease recovery time as they become mentally aware and trusting of their prosthetic appendage.

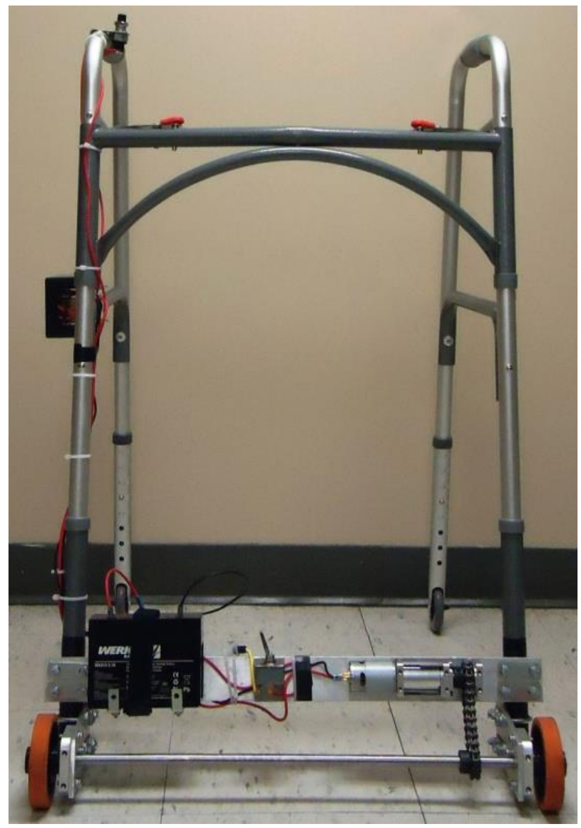


Fig. 16.1. Final Design of Motorized Walker without the Chain Cover.

TECHNICAL DESCRIPTION

Figure 16.1 illustrates the final device which consists of two robotic 4” wheels mounted on an axle at the front of a Deluxe Bariatric Heavy-Duty Walker. Two universal 3” walker wheels were attached to the back. An rs550 Banebots® motor was attached to a p60 Banebots® gearbox. A 5.1 Amp-hour rechargeable battery was attached to a 30 Amp fuse, toggle switch, a momentary switch, the motor and the variable speed controller (Figure 16.2 (Top)). The toggle switch is designed to control the battery and was installed on the front of the walker. The physical therapist flips the switch in the proper position for the user. The momentary hand switch was mounted on the right walker handle and will be used by the user to control motion. The battery is designed to last approximately 30 minutes; the standard time for a physical therapy training session. The variable speed controller was selected because it could alter the power of the motor without sacrificing the torque and can be controlled by the physical therapist based on user stride. The switches were included such that if the user removed his or her right thumb from the switch (for instance, during a fall), the circuit will break, causing the motor to cut off and the front wheels to lock in place. Figure 16.2 (Bottom) shows the safety chain cover installed, which also helps to mute the noise of the motor. Total cost = $1,279.

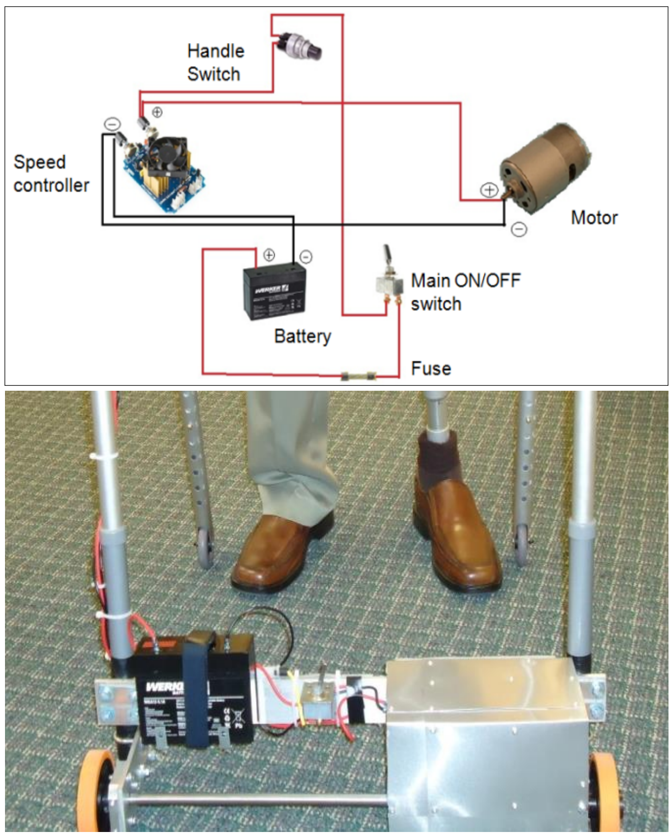


Fig. 16.2. (Top) The Circuit of the Motorized Walker; (Bottom) Front View of Device being used with the Chain Cover in place, which also Provides Some Noise Reduction.

A BALANCE TRAINER FOR ADULTS WITH CEREBRAL PALSY

Designers: James Yearty, Ankit Kaushik, Victor Phillips, Daniel Kennedy
Client Coordinator: Amanda Favret, OTR/L, LINCPoint (UCP of Greater Birmingham)
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
Department of Biomedical Engineering
University of Alabama at Birmingham
Birmingham, Alabama 35294

INTRODUCTION

Cerebral palsy (CP) is a broad term encompassing a group of non-progressive, non-contagious motor conditions that cause physical disability in the form of body movement. Due to the degenerative nature of the condition, persons with CP (especially those confined to wheelchairs) should be encouraged to use various muscle groups of the upper and lower body to prevent muscle breakdown and to improve their physical and cognitive abilities. One severe limitation is that many affected individuals lack the proper posture and balance to perform everyday tasks. In addition, mental impairments are common in many CP cases, and therapy regimens must be developed with this factor in mind. A device was needed by physical therapists (PT) at LINCPoint (United Cerebral Palsy (UCP) of Greater Birmingham) to train adults with CP proper balance using the muscles of their upper torso. It should conform to the safety and stability of current on-market balance trainers, but still meet the needs of LINCPoint therapists and their patients. The clients asked that the device utilize audio-visual cues and a passive method of inducing a loss of balance. The device would allow freedom of movement of the occupant so that therapeutic exercises may be performed while in the device and supervised by a PT.

SUMMARY OF IMPACT

An adaptive balance trainer was developed which integrates a therapist controlled, positive biofeedback system, into a safe and stable therapy platform. The device will be used by our clients at the LINCPoint facility to provide their patients with safe and efficient physical balance therapy.

TECHNICAL DESCRIPTION

The final design, shown in Figure 16.3, consists of a barber's chair frame to which was attached a BOSUTM balance seat and an integrated audio-visual system. The BOSU seat provides a convex seating surface which passively induces loss of balance. A lap-style seatbelt was attached to ensure that the user cannot fall out of the chair. A "pommel" and a footplate were added to the barber's chair to support the lower extremities. Several mounting brackets were added to the backrest, seat, and undercarriage of the barber's chair frame and mounted onto "gooseneck" tubing. The audio visual system consisting of a pair of LED arrays attached to brackets on the backrest of the chair. The gooseneck tubing allows for freedom for positioning of the LEDs. An iPod serves as the musical source which is amplified and projected through a pair of BoseTM speakers mounted in a basket behind the user for optimal positive reinforcement. Thus, all users may benefit from the audio-visual cues regardless of size or anatomical orientation. The audio-visual system is controlled via a wireless remote that controls a set of 3 appliance outlet switches. The presiding occupational therapist is given complete control of the device's function, increasing the effectiveness of therapy regimens. Total cost = $1261.

Fig. 16.3. The Balance Trainer (left) along with the LED lights and flexible gooseneck arms (top right), the wireless remote system (Middle Right), and the speakers (Bottom Right).

THE BUMBO-SEAT WHEELCHAIR TRAINER

Designers: Raymond Chow, Harrison To, Sean Pool
Client Coordinator: Marliese Delgado, OTR/L, Hand-in Hand (UCP of Greater Birmingham)
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
Department of Biomedical Engineering
University of Alabama at Birmingham
Birmingham, Alabama 35294

INTRODUCTION

Children with lower limb partial paralysis resulting from cerebral palsy or spina bifida have a much more challenging time interacting with their environment than do their peers who do not have impaired mobility. Such interaction is crucial to the development of children's motor cortex as well as their cognitive abilities, especially during their earliest years. The earlier a child can gain independent mobility, the better chance he or she has of overcoming developmental disabilities and learning new ways to accomplish challenging tasks. Marliese Delgado, MS, PT, from Hand-in-Hand of United Cerebral Palsy of Greater Birmingham requested an early-stage wheelchair-training device for children with lower limb partial paralysis resulting from cerebral palsy or spina bifida. She indicated a desire to incorporate a Bumbo Seat - a stationary sitter of molded plastic for children between 6 months and 2 years of age, commonly advertised for providing posture support and therefore increased field of view, improved breathing, and easier feeding. The Bumbo Baby Seat Wheelchair Training Attachment would provide a lightweight, sturdy, and removable attachment to commercially available Bumbo chairs for children ages 8 to 24 months with cerebral palsy and spina bifida.

SUMMARY OF IMPACT

This device will help children develop the muscular control and confidence to independently operate a pediatric or standard-sized wheelchair in later years, ultimately enriching their cognitive and social engagement while reducing the need for future treatments. The compact design of the device allows children to closely approach objects of interest, including toy boxes, bookshelves, and tables. The Bumbo seat attachment elevates the sitter to a height of 6-inches, thus ensuring the user will be at eye-level with his or her peers when they are seated in the chairs at the daycare. A collapsible handle allows for interaction and intervention by the parent/therapist.

TECHNICAL DESCRIPTION

A CAD drawing of the main structure and the extended rear handle are shown in Figure 16.4. Key features of the wheelchair-training attachment include main wheels that are comfortably positioned for easy self-propulsion by the user, which imitate the biomechanics of manual wheelchairs. The wheels add details were selected for the resistance to heat (playground surfaces in Alabama may reach 170^{0}F). The main structure and footrest were machined from a series of custom dimensioned blocks of medium density fiberboard (MDF). The adjustable rear handle for adult-facilitated movement was positioned in a MDF piece angle cut and hollowed out. Swivel casters attached beneath the base of the attachment provide added stability when crossing uneven surfaces, such as door frames. A footrest was provided for added body support that will not inhibit the proximity to which the wheelchair attachment can approach objects of interest. The device also has a seat belt for added safety, and is shown being used by a child with cerebral palsy in Figure 16.4. Total cost = $328.

Fig. 16.4. Bumbo Baby Seat Wheelchair Trainer: (Left) CAD drawing; (Right) Child at Hand-in-Hand using the device (picture released with parental consent).

A SEIZURE INDUCING DEVICE FOR MANIKINS USED IN PEDIATRIC MEDICAL TRAINING

Designers: Jelaina Scott, Vinuta Mayakonda, Iman Tamimi, and Hannah Burt
Client Coordinator: Nancy Tofil, MD/PhD, Children's Hospital of Alabama
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
Department of Biomedical Engineering
University of Alabama at Birmingham
Birmingham, Alabama 35294

INTRODUCTION

Seizures are common. One in every ten people will experience at least one in their lifetime; therefore, it is essential that medical staff is trained to respond to them in a timely and adept fashion. Simulation education provides a new way to train prospective and practicing health professionals to enhance their learning and quicken decision making in critical care units. The American Association of Medical Colleges (AAMC) issued a report in September 2011 which alleged that every hospital and other health professional training institution have either a simulation center, simulation equipment, or a simulation-based education program.

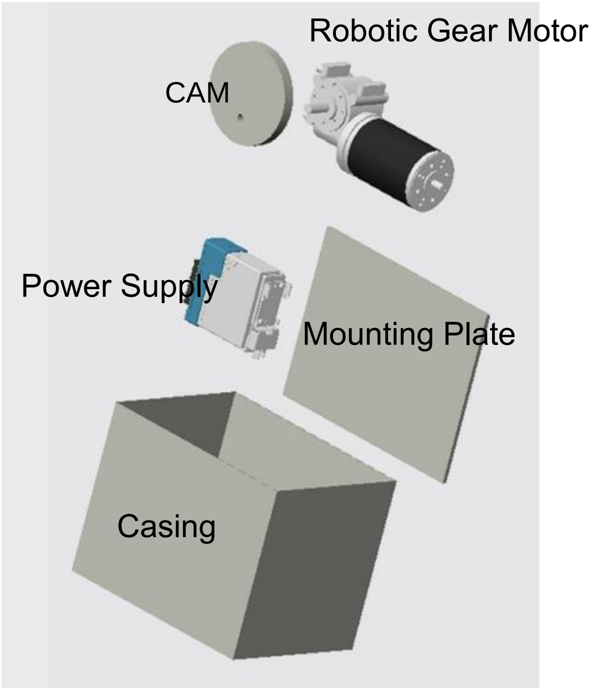
Our client expressed a need for a device capable of producing safe, effective, and realistic seizures in health care training manikins. Existing devices are far too expensive and are incapable of reproducing the amplitude of convulsions that are representative of real seizures. The present design was developed to enable Dr. Nancy Tofil and other instructors at the Children's Hospital of Alabama, Pediatric Simulation Center to accurately and effectively simulate seizures on child-sized anatomical manikins. Device constraints included frequency of vibration (1-4 Hz) and amplitude (> 1 inch) to simulate convulsions resulting from a seizure. In addition, the device should be hidden from site of the trainee and be operated remotely from behind a curtain where the instructor is stationed during the simulations.

SUMMARY OF IMPACT

Staff at the pediatric simulation center will use the seizure simulation device in order to simulate convulsions resulting from seizures on the manikins, and effectively train health care professional students on how to treat symptoms related to seizures. The effectiveness of the device will be measured based its ability to produce realistic convulsions with the proper amplitude and frequency.

TECHNICAL DESCRIPTION

For the final design, the design team arrived at a robotic motor controlled CAM system that translates rotational motion of the motor shaft to linear motion through the CAM, which induces lifting of the back of the manikin under which it lays. The motor (AME 218-series 12V 212 in-lb. LH gear motor with stubby shaft) is encased in a box along with its power supply (Common Sense 100 Watt AC Power Supply), which is nested within egg crates to blend in with a hospital bed. The motor drives an offset circular CAM (2 inch diameter) which lifts the lid of an aluminum box positioned beneath the manikin. This serves to preserve the realism of the simulation experience, an integral part of simulation training success. The robotic gear motor was selected for use in the device due to its low heat generation and minimal noise production qualities, in addition to its capability to support high loads at high speeds, and was selected based on its torque and rpm specifications. Figure 16.5 shows a CAD drawing of the device and its major components, the final cam-motor assembly, as well as an illustration of the mechanism by which the cam lifts the manikin. Final cost = $398.



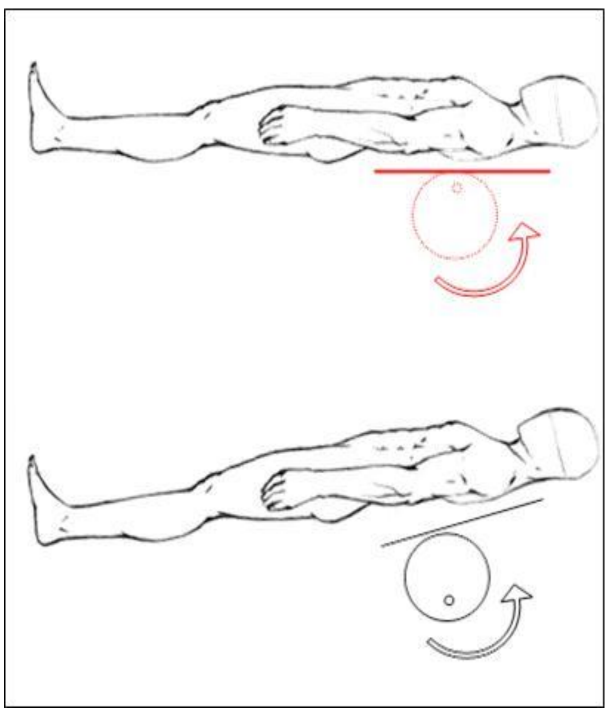


Fig. 16.5. (Top Left) Exploded CAD drawing of device components; (Top Right) View inside completed device showing motor and offset CAM lobe; (Bottom) Illustration of how the system induces upward motion of the manikin for seizure simulations.

SENSORY STATIONS FOR TRANQUIL WATERS

Designers: Amber Burns and Sara Lee
Client Coordinator: Sandra Fornes, Tranquil Waters
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
Department of Biomedical Engineering
University of Alabama at Birmingham
Birmingham, Alabama 35294

INTRODUCTION

The Christopher Douglas Hidden Angel Foundation (CDHAF) is a non-profit organization focused on enriching the lives of children and adults with disabilities through multi-sensory stimulation. The organization has donated over 35 multi-sensory environments (MSE's) across the USA and Canada to serve people with conditions including autism, cerebral palsy, hearing impairments, developmental disabilities/delays, and dementia. These MSE's include elements that can provide visual, tactile, olfactory, auditory, and movement stimulation. Frequent interaction with such MSE's has been shown to improve the quality of life of individuals with disabilities. Furthermore, similar environmental enrichment has been found to affect neurological processes in animal studies of neurodegenerative diseases. Thus, these MSE's may be able to benefit individuals with cognitive disabilities on a neuro-biological level.

The headquarters of the CDHAF is located near Birmingham, Alabama, at a sensory park called Tranquil Waters. This facility seeks ultimately to have outdoor sensory stimulation stations located throughout the park. Tranquil Waters additionally serves as the residence of its founders, Sandra Fornes and Bud Kirchner, this project's clients. They requested outdoor multisensory stations at Tranquil Waters to enrich the lives of children with needs and promote interactions between visitors. Design constraints were imposed such that each station should be structurally stable, blend with nature, and pose no harm to visitors; materials should be weather-resistant, durable, easy to clean, resistant to UV degradation; the stations must be accessible to individuals in wheelchairs, and should provide multi-sensory stimulation to individuals with disabilities ranging from severe cognitive and physical disabilities to minimal disability. In addition there should be no removable parts <1.75 inches and each station should require minimal electrical requirements.

SUMMARY OF IMPACT

The pilot station completed by this team has parts that provide passive sensory stimulation, as well as elements that promote active interaction. Bright colors against a neutral background draw visitors towards the station. A light breeze will additionally cause dangling ropes to sway, and can cause the chimes to produce sounds. Once at the station, a visitor can feel the many different textures, temperatures, sizes, and depths of the elements. Parts can be easily manipulated, often to produce a sound, so that visitors will be able to influence their environment without the intimidation associated with operating more complex systems. Because the stations designed for this project provide multi-sensory stimulation, they can be part of a therapy program for individuals with special needs.

TECHNICAL DESCRIPTION

The completed station consists of a permanent frame and a removable insert which supports the sensory elements. The permanent frame consists of two posts set in concrete, support beams for the insert, and a roof. The lowest part of the roof is 8′ from the ground to prevent visitors from attempting to climb on it. A beam runs between the two posts on which the insert rests. Each post has an attached board to serve as rails for the insert. Hinges on the back rails allow the insert to be removed from the frame, while latches prevent visitors from opening the rails and being harmed.

The insert measures 3′ high by 4′ wide, and 3.5″ thick, with an outer frame made of 1″ by 3.5″ boards. The insert has a plywood backing on which interactive elements are attached, as shown in Figure 16.6, including ropes connected to wind-chimes and levers that can be pulled to cause xylophone keys to be struck. Safety precautions included rounding corners/edges, firmly securing small objects to prevent choking hazards, and ensuring that protruding objects would not pose harm if accidentally struck. Ease of use and accessibility were maximized, however, it was expected that some visitors with more severe motor disabilities would require the assistance of an attending care-giver to interact with the sensory elements. Total cost = $593. Other interchangeable inserts were under construction at the time this report was submitted.

Fig. 16.6. (Left) Completed station at Tranquil Waters, not showing roof. (Right) Closer image of the insert. On the left is a system of levers that operates the xylophone bars behind clear acrylic sheeting. The colorful wooden levers can be pulled, or the short line attached to each bar can be used to strike one of the xylophone bars. At the bottom of this half is a wooden boat cut-out that can be slid along a track of waves. On the right side of the insert are several chimes behind acrylic sheeting. Each sound element has a connected rope or chain that can be pulled on from below to create a sound. Different sizes of rope and chain, as well as the UAB letters attached to the back provide additional tactile stimulation.

SHOULDER REHABILITATION DEVICE

Designers: Jitesh Patel, Michael Elhajj, Jarrod Young, Timothy Driskell
Client Coordinator: Sandra Fornes, Tranquil Waters
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
Department of Biomedical Engineering
University of Alabama at Birmingham
Birmingham, Alabama 35294

INTRODUCTION

Dr. Brent Poncé, an orthopedic surgeon at the UAB Highlands has requested a device that improves upon the current solutions for shoulder, specifically rotator cuff, rehabilitation for post-operative patients. Current methods of shoulder rehab, while effective, can be improved to make the process more efficient for the therapists and patients. Additionally, the safety of the process can be improved to prevent further injury to the wound site. To determine how to improve on the rehab process, the team consulted with Dr. Poncé, for a clinical perspective, Drs. Alan Eberhardt and Dale Feldman, for engineering analysis, and Michael Stallworth, PT, for the perspective of a physical therapist. After consultation, Dr. Poncé requested a device that will perform all the necessary exercises for post-operative patients to regain maximum shoulder functionality with considerations to ensure safe and proper use. Additionally, Dr. Poncé requested the device be portable to be stored and moved within the rehab environment as well as potentially portable enough for patients to take outside of the rehab environment to complete their exercises at their convenience. Upon completion, the device will be turned over to Dr. Poncé to be used at Workplace, the physical therapy department in association with the UAB Highlands, by post-operative patients.

SUMMARY OF IMPACT

The complete shoulder therapy device will be used by post-operative patients at UAB Highlands to regain maximum shoulder functionality. The device improves on current rehab methods by supporting all necessary exercises to complete rotator cuff rehab in a single, portable platform. Releasing the device to Dr. Poncé and Workplace will allow for testing and feedback or the current design. With the critiques and recommendations of Dr. Poncé and the Workplace physical therapists, the device can be assessed and further modifications made if necessary.

TECHNICAL DESCRIPTION

The device can be broken down into four primary subsystems: attachment, adjustment, exercise platform, and exercise equipment. The attachment subsystem consists of two ratcheting, horizontal support bars that can fit into multiple doorframe sizes. The lower bar is attached to the vertical pole (adjustment subsystem) through an eye bolt, allowing for easy and efficient installation. Attachment with an eyebolt allows the support bar to be rotated 360^0 for compact storage when not in use. The top support bar is the first part installed into the doorframe and supports the device by a hook on the vertical pole that hooks over the bar. The next subsystem is the vertical pole that allows for adjustment of the exercise platform. A two inch outer diameter, 36 inch long aluminum pole allows the exercise platform to be height adjusted in increments of three inches to accommodate all exercises for patients of several heights. Finally, the exercise platform is a six inch long aluminum tube with an outer diameter of 2.25 inches that fits around the vertical pole. A t-handle pull pin is welded to this part to allow patients to easily adjust the height of the exercise platform with one hand, preventing further injury to the wound site. Additionally, a hook is welded to this part that holds the exercise equipment. This equipment consists of a rope and pulley system that allows patients to perform passive exercises, a retractable pulley that assists in active exercises and Thera-bands that assist in performing resistive exercises. These parts can be interchanged by the physical therapist depending on the stage of rehab the patient is in. Finally, to prevent injury to patients in the early stages of rehab, safety factors have been incorporated into the device. The passive rope and pulley system has colored markings on the rope at 15^0 intervals so patients can physically see when they have reached the range of motion designated by the physical therapist. Additionally, a magnetic clip can be attached to the rope at the colored sites for patients performing exercises facing away from the device.

When coming in contact with the pulley, this clip will provide a slight resistance to patients and signal that they have reached the desired range of motion and can now relax. A computer generated image of the device is shown in Figure 16.7. Total cost = $461.

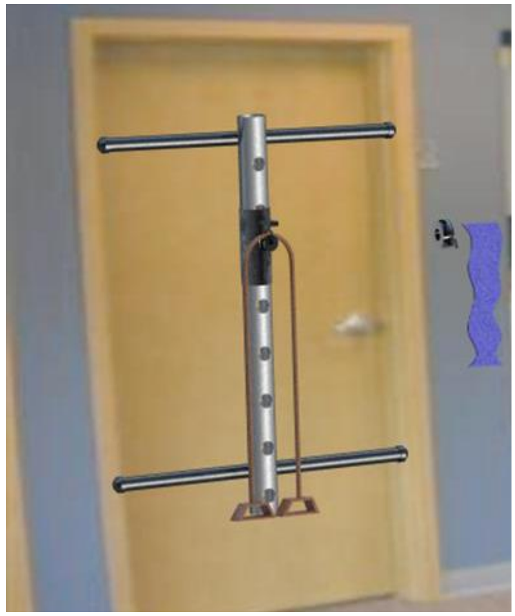


Fig. 16.7. Computer rendition of portable shoulder rehabilitation device. The device fits in a doorway and provides the user with multiple attachments for passive, active and resistive exercises.

BAMBOO WALKERS FOR ZAMBIANS WITH DISABILITIES

Designers: 16 STH 201 students
Client Coordinator: Alan Eberhardt, PhD
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
Department of Biomedical Engineering
University of Alabama at Birmingham
Birmingham, Alabama 35294

STH 201 Research Approaches in Engineering is a course for freshmen in the Science and Technology Honors program, which involves an introduction to the principles of engineering mechanics and materials, with an emphasis on engineering design. The students are introduced to computer-aided drawing (CAD), computer-aided manufacturing (CAM), machining processes, mechanical testing and failure analysis using light and scanning electron microscopy. This year, a 5 week design activity was included where 5 teams of 3-4 students worked to develop walkers, using sustainable materials for use by an average man, woman or child (6-10 years old) in Zambia. The design constraints included the use of sustainable materials available to Zambians (bamboo, sisal twine, wood glue, leather and burlap). The use of power tools was forbidden. The overall goal was to provide devices that could be translated to the developing SIFAT Center for mass production and use by local Zambians. In the first related lectures, the students were introduced to the design problem, EWB and SIFAT, and the associated issues of sustainability in developing countries like Zambia. Next, they were exposed to concepts in engineering design including statics & free body diagrams, column buckling, stress analysis, and material selection and analysis using the CES Edupak software (Granta, Cambridge, UK). The students were required to present their final projects as oral presentations (using PowerPoint), which was done as a team. Overall, 5 different walkers were completed, an example of which is shown in Figure 16.8. Estimated cost/device = $30.

Fig. 16.8. Example completed bamboo walker, which featured a fold down seat, so Zambians could rest easy between uses of the walker to assist in ambulation.

CHAPTER 17
UNIVERSITY OF MASSACHUSETTS-LOWELL

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MODIFIED HOSPITAL BED CONTROLLER: A DEVICE THAT ALLOWS THOSE WITH SEVERE CEREBRAL PALSY TO OPERATE A HOSPITAL BED

Designer: Alexander W. Duchane
Client Coordinator: Tom Mercier, Assistive Technology Services DDS, Hawthorne, MA
Supervising Professor: Donn Clark
Electrical and Computer Engineering Department
University of Massachusetts Lowell
Lowell, MA 01854

INTRODUCTION

The modified hospital bed controller was designed to provide my client with the ability to control her powered bed by herself. The controller is attached to the bed. The controller uses large buttons to determine which part of the bed will be raised or lowered then a joystick is used to raise and lower the different parts of the bed. This is important because my client has very poor muscle control. She can't hold the controller or hold down the buttons for a prolonged period of time, but she does have enough control to push a button. The controller will also allow her to save positions, so she can quickly go from watching TV to her sleeping position. The purpose of this project is to give my client as much independence as possible, because companies design their devices with the idea that a nurse or helper will be operating them and not the disabled person.

SUMMARY OF IMPACT

This device will provide disabled people with more independence and comfort. Even though my client is handicapped, she has fully functional mental capabilities as do many in her condition. This device will greatly improve her quality of life by allowing her to control the bed herself and not have to rely on someone else.

Fig. 17.1. Picture of Completed Controller.

TECHNICAL DESCRIPTION

The modified hospital bed controller can be broken down into three parts: the circuit, the case with arm attaching it to the bed, and the firmware which allows the controller to save bed positions data. The case is a plastic box which contains the circuit board. The buttons and joystick are attached through holes drilled in the box and then are wired to the circuit board. The arm is made from a drum stand and clamps directly to the bed rails. The controller is 4.5 inches wide, 8 inches long, and 2.25 inches tall. The controller arm is 24inches long which can be extended or retracted by sliding it along its mounting point. It also has a pivoting arm that will allow the box to be adjusted to the client's needs.

The circuit assembly is based around an Arduino Diecimila board. This board was used because it allows for the power rectification of the batteries. Eight AA batteries are used to power the device. A

5V output from the board goes into seven sets of switches. Each switch is set to short one resistor in a voltage divider so when the button is pressed the voltage across the other resistor goes high. The Arduino board then reads this new input and reacts by the firmware. The outputs from the board go to six relay switches. When the Arduino board outputs high, it will energize one of the relays, which will complete a circuit with the bed, raising or lowering one of the parts.

The firmware is based off of several while loops. When one of the buttons corresponding to a part of the bed: head, body, or feet, is pushed, the controller then waits for the joystick to be moved. When the joysticks in moved forward the part of the bed moves up and a counter associated with that part of the body increases. When the joystick is moved downward the corresponding part of the bed lowers and the counter decreases. When the save control button is pressed along with the save slots; the bed will save the counters to the save location. When the save slot is pressed again without the save control button being pressed first, the bed will raise and lower until the saved counters and the bed counters are the same.

The largest cost of this project was in the switches and relays followed by the Arduino. The 8 switches were $7.02 each, for a total cost of $56.16. The relays cost $3.23 each, for a total cost of $25.84. The Arduino processor cost $25.00. The rechargeable batteries and charger cost $24.00. All the other parts including the case, wires, and resistors came to about $20.00, for a total cost of $151.

Fig. 17.2. Unassembled Case Assemblies.

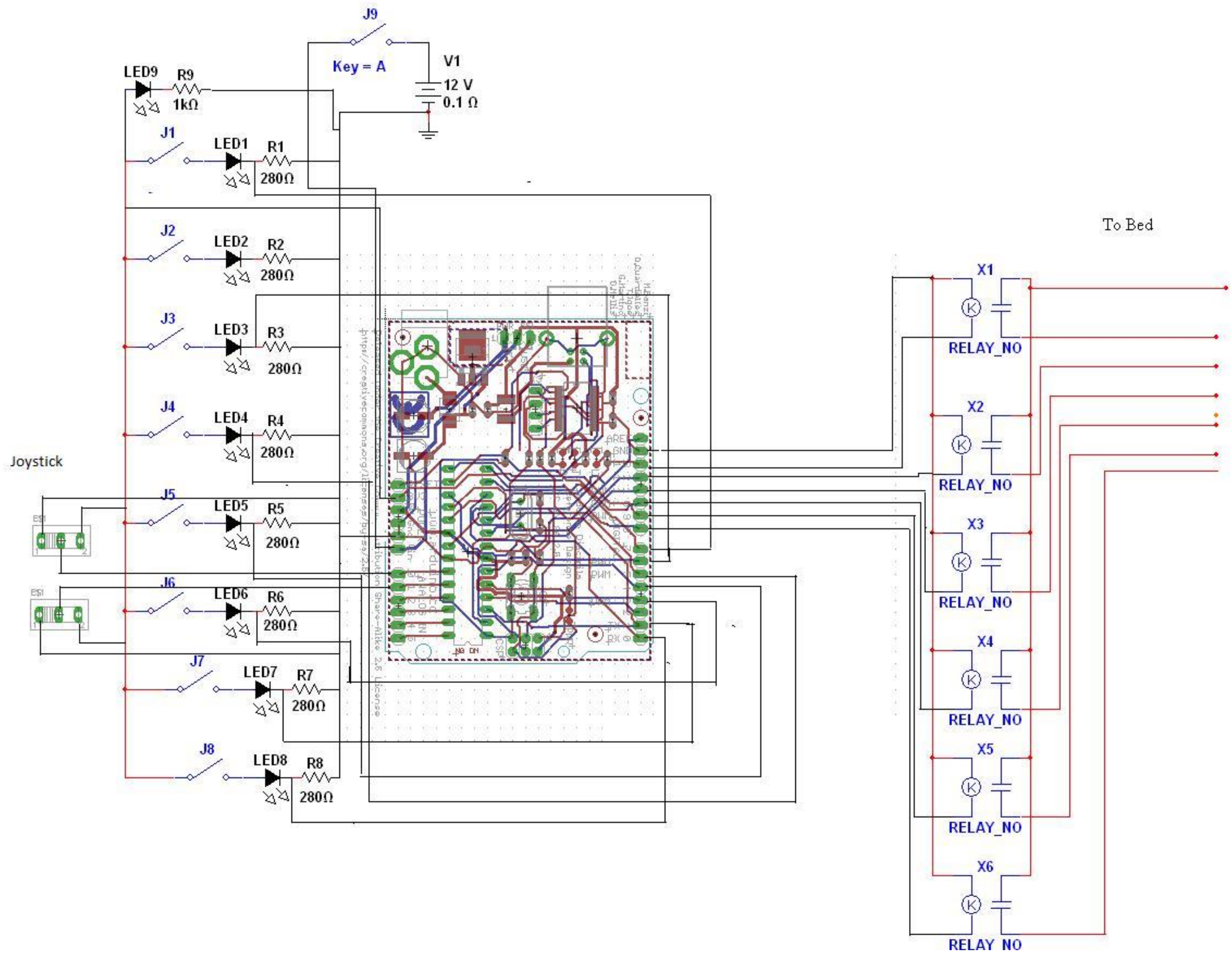

Fig. 17.3. Full Circuit Diagram.

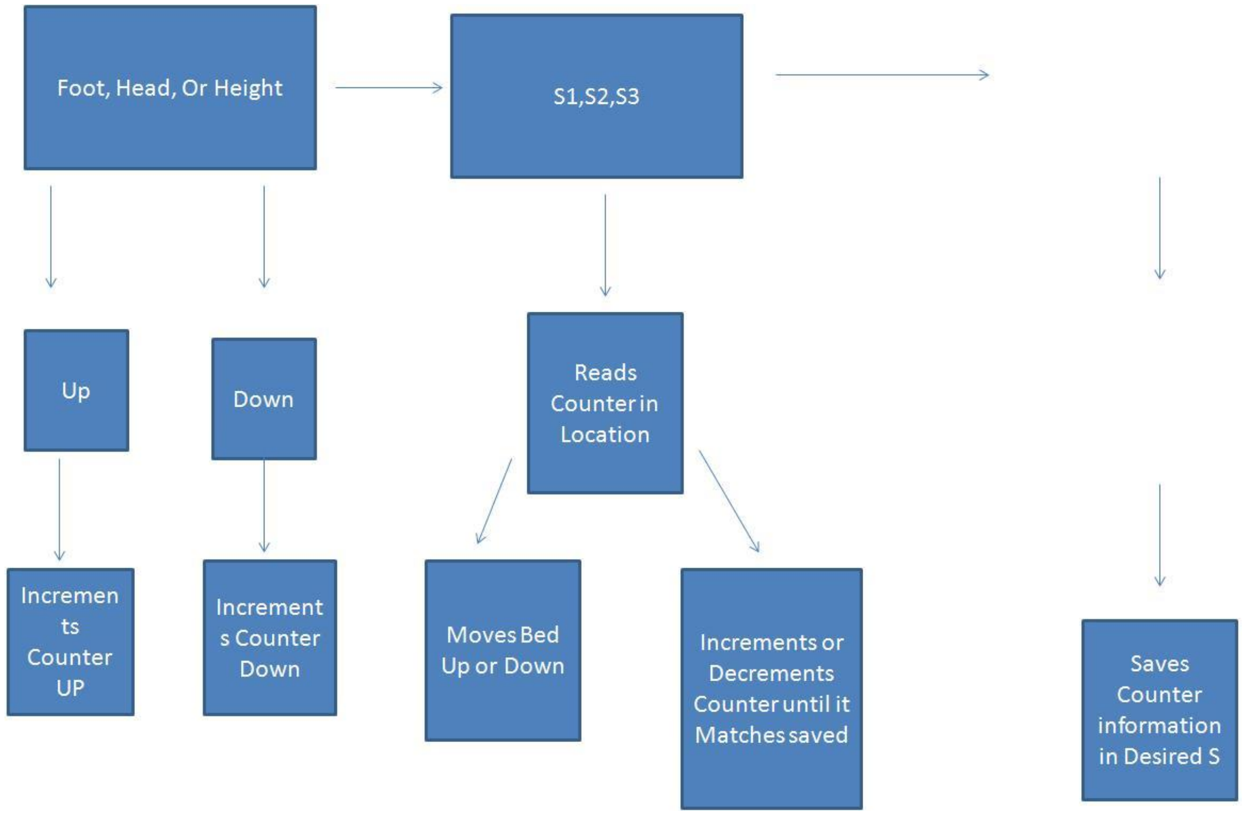

Fig. 17.4. Diagram of Code.

THE COASTAL CONNECTIONS COMPUTER WORKSTATION: A DEVICE THAT PROVIDES COMPUTER ACCESS TO PEOPLE WITH DIFFERENT DISABILITIES

Designers: Austin Chenelle, Alan Mattila, and Hristos Tsiakalos
Client Coordinator: Deborah Plumer, Coastal Connections Inc., Amesbury, MA
Supervising Professor: Donn Clark
Department of Electrical and Computer Engineering
University of Massachusetts Lowell,
Lowell, MA 01854

INTRODUCTION

The Coastal Connections Computer Workstation (CCCW) was designed to provide computer access to the internet and other computer applications for people with multiple handicaps. The computer has a custom graphical user interface (GUI) with big and easy to click buttons. The easy to use applications are represented by 300 x 300 pixel buttons that include the name of the application along with a graphical icon (see Figure 17.5). Upon completion, the CCCW was presented to Coastal Connections Inc. in Amesbury, Massachusetts. The people at Coastal Connections have varying disabilities, both physical and cognitive. Through the use of a joystick and button access combined with a simple user interface; those with limited capabilities can access music, video, picture programs, and an internet browser. This workstation provides computer access for individuals who were previously unable to enjoy the utility of a personal computer system. Ultimately, the CCCW is intended to give independence to the user by enabling them to interact with music, videos, pictures, and the internet.

SUMMARY OF IMPACT

The design criteria for the CCCW were defined by the capabilities of the potential users and the need to have a computer at Coastal Connections accessible by the team. Coastal Connections services a large number of local people and one-on-one staffing is not always feasible. In order for an individual to use the CCCW, the Coastal Connections staff will not need to be deeply involved. The user will have complete control in operating the computer. Whether it is to listen to music, watch a movie, or search the internet, the user will be capable of doing so without any assistance. The CCCW helps Coastal Connections to achieve its goal of service to the community without being an extra burden for staff (see Figure 17.6).

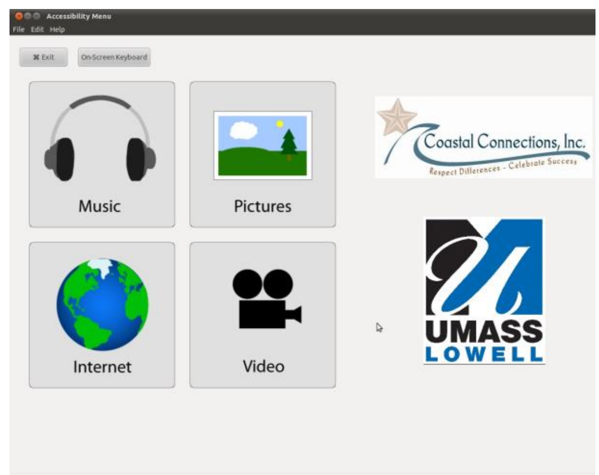

Fig. 17.5. The Coastal Connections Computer Workstation Interface.

TECHNICAL DESCRIPTION

The overall project was created around a donor desktop computer. The computer's components were upgraded in order to support all graphical and multimedia requirements of the CCCW. In the interest of programming flexibility, the latest Ubuntu Linux operating system was installed. By using the Ubuntu operating system, the use of a large open source programming community was accessed. Ubuntu distributions are prepackaged with a programming framework called Qt4, a suite that is developed by the Nokia Corporation. Nokia's Qt4 provides the user with a rich library of extensive documentation, and full support of C and C++ programming languages. All programs and GUIs on

Fig. 17.6. Coastal Connections individuals receiving the CCCW.

the computer were designed using this framework. In addition to software programming, CCCW's design required a good portion of hardware. The PIC18F2550 chip developed by Microchip Technology Inc. was used as a USB microcontroller to provide user access to the desktop computer. Through Microchip's own MPLAB IDE software, code was written, built, and transferred to the PIC18F2550. This code allowed connectivity between an arcade style joystick and buttons and the computer via USB (see Figure 17.7.). Upon connecting this custom device to the computer, it was recognized as a USB standard Human Interface Device (HID) and provided instant control of the mouse cursor on screen.

Fig. 17.7. Joystick and Jelly-Bean Button.

The cost of parts/material was about $700.

THE EDIT READ TALK SYSTEM

Designers: Brian Zanchi, James Stadtmiller, and John Lippiello
Client Coordinator: Patty Peterson, Bridgewell Center, Lynn, MA
Supervising Professor: Jim Drew
University of Massachusetts Lowell,
Lowell, MA 01854

INTRODUCTION

The Edit Read Talk System (ERT) was designed to provide easy access to the outside world via the Internet for adults with different handicaps. This device consists of a software interface with a simplified mouse and keyboard. With the software installed on a computer, the user can access the internet and import a text article to be read by the computer. The simplified keyboard consists of the arrow keys for easy navigation, the enter button, a shortcut to increase/decrease the text size, and to open and close the ERT program. The mouse was designed using an accelerometer to detect head tilt which allows the user to control the mouse pointer by tilting his or her head. Users can also type by using an onscreen keyboard with the mouse. A left-mouse button was added to allow users to control the computer. The ERT system can be used by people to easily access online articles and get the latest news without regard to their level of handicap. A picture of one of the users along with the designers is shown in Figure 17.8.

SUMMARY OF IMPACT

The design criteria for the ERT system was defined by the Bridgewell Center. Many of the clients at the Bridgewell Center have low reading skills and have difficulty reading articles that interest them. As a result, Bridgewell requested a system that can read Web- based text back to the user. Some of the users have additional handicaps that impair their ability to use the standard hardware on a computer. Additional hardware was designed and created so these clients can more easily access technology.

TECHNICAL DESCRIPTION

The ERT hardware system was constructed using various materials. To ensure durability, the keyboard was built out of wood and finished with a stain and clear coat. It was also easy to construct compared to plastic or metal. Each of the two 5/16” diameter buttons are mounted on the top of the box and requiring only two grams of pressure to activate.

Fig. 17.8. The ERT System Hardware Diagram.

There are a total of nine buttons on the keyboard: 1.) OPEN ERT, 2.) CLOSE ERT, 3.) READ, 4.) STOP, 5.) Left Arrow, 6.) Right Arrow, 7.) Up Arrow, 8.) Down Arrow, 9.) ENTER. An additional button is attached separately by a cable that provides a left mouse click. Each of these buttons were attached to a PIC microcontroller with a USB module built in. Figure 17.9 shows the layout of the ERT.

The motion mouse box was constructed from a standard plastic project box and consisted of a 3-axis accelerometer mounted on the inside. This was then connected to a separate PIC microcontroller that was used for the mouse. The microcontroller’s Analog to

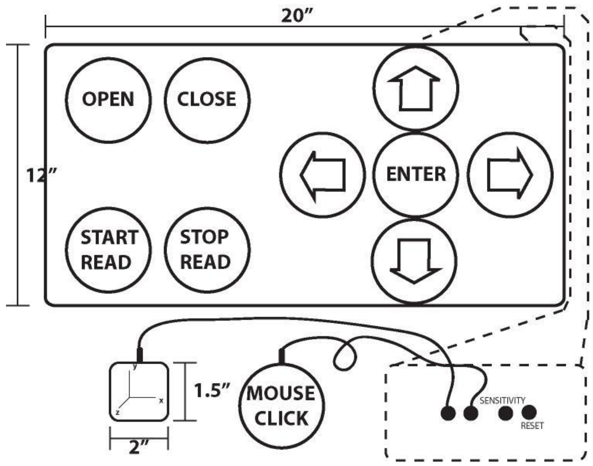

Fig. 17.9. Layout of ERT Keyboard.

Digital Converter (ADC) was used to determine the change in tilt from its nominal position which was then translated to a movement of the screen's pointer. A mouse click was included by using the same button as used in the keyboard. This button was designed to provide the user with a left mouse click. Also, a sensitivity setting was included along with a reset button. The sensitivity setting consists of a potentiometer where its position determined the movement multiplier (1-4). This potentiometer was attached to a channel of the ADC and is available to the user on the back of the keyboard. The reset button was used to reset the nominal position of the accelerometer. Do to limitations of the PIC's memory; the accelerometer mouse is limited to the x-y plane when the user's head is facing the screen.

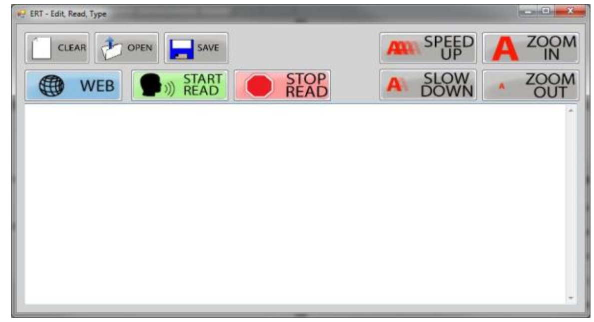

Fig. 17.10. Screenshot if E.R.T Program.

The main software application was created with Microsoft Visual Basic and runs in conjunction with free text-to-speech software created by NaturalSoft. The user interface provides users with the ability to open, edit, and save text files. In addition, any text within the editor can be read by the computer using commands within visual basic to signal the text-to-speech software to activate. Since some users may have trouble seeing the text on the screen, a zoom function was incorporated. A user can control text size by clicking buttons within the application or by pressing keyboard shortcuts. In addition, a Web-browser was built into the application which can be launched from the main application window. In order to limit the text that is read by the reader, the user navigates to the desired web page and clicks the import button. ERT then copies just the main pages text into the reader to prevent for things like menus and advertisements from being read. A screenshot of the application window is shown in Figure 17.10.

THE SPEECHSENSE (SS): INSTRUCTIONAL DEVICE AND SOFTWARE PROVIDING VISUAL AND TACTILE FEEDBACK IN SPEECH THERAPY APPLICATIONS

Designers: Gabriel Sikarov, Daniel D'Amato, Joseph Collins
Client Coordinator: Charlotte Lunde, Horace Mann School for the Deaf and Hard of Hearing, Allston, MA
Supervising Professor: Donn Clark
Electrical and Computer Engineering Department
University of Massachusetts Lowell,
Lowell, MA 01854

INTRODUCTION

The SpeechSense (SS) was designed to provide visual and tactile representations of sounds incident on the system to deaf and hard of hearing patients involved in speech therapy. Consisting of software that provides three colored meters to represent low, middle, and high frequency sounds and a box that vibrates three different parts of the patient's hand, the SS is meant to help deaf and hard of hearing patients perceive what sorts of sounds their instructor and the patients, themselves, are producing. By attempting to recreate the visual and tactile feedback produced by the SS during an instructor's vocal demonstration, deaf and hard of hearing students can practice enunciation of sounds. The SS gives patients an intuitive metric by which to gauge the accuracy of their enunciation.

Fig. 17.11. The SpeechSense System.

SUMMARY OF IMPACT

The design criteria for the SS required it to be: 1) intuitive to use and understand across different age groups, 2) portable, 3) occupy a small surface area, and 4) be compatible with computer systems currently available to the client. The clients are able to run the software and hardware from any Windows PC. Additionally, the speech therapists have an effective method of demonstrating to patients the type of response the patients need to emulate in their enunciation.

Fig. 17.12. The SpeechSense Hardware.

TECHNICAL DESCRIPTION

The SS hardware consists of a box connected via USB and analog audio cable to a computer. The box (9.5 by 8.1 by 1.5 inches) has a foam hand print, on which the patient lays his or her hand. Three vibration motors lie under the thumb, middle, and small fingers of the hand print. Motors vibrate with intensities proportional to the low, middle, and high frequency sound levels produced by the patient. For example, if a patient makes a high frequency /s/ sound at a moderate volume, the patient feels his or her small finger vibrate with a moderate intensity. Doing the same with a low frequency sound, such as /o/, the patient feels their thumb vibrate at a moderate intensity. This is achieved with a microphone which converts the acoustical energy the patient produces into electrical energy. The electrical signal is sent into the computer's microphone jack through analog cables, and is processed using a third party Fast Fourier Transform (FFT) algorithm. The SS software then sends vibration commands over the USB cable to a third party Peripheral Interface Controller (PIC) microcontroller. Subsequently, the PIC controls the intensity of vibration for the respective motor.

The software displays three colored bar meters that correspond to the sound level of the low, medium, and high frequency sound being inputted into the system. The software allows the instructor to record a word enunciation for the patient by selecting "teacher mode", and allows the patient to replay and study the visual and tactile feedback produced by the instructor's recording. The patient then attempts to repeat the sound the instructor produced by selecting the "student mode" and attempting to recreate the feedback produced by the instructor's recording. The software performs all FFT analysis, displays the sound meters, initiates tactile stimulation, and selects which of the two microphones, patient microphone or instructor microphone, is active at a particular time.

The cost of parts/materials was about $168.

Fig. 17.13. Deaf Student Using the SpeechSense System.

Fig. 17.14. Hard-of-Hearing Students Using the SpeechSense System.

THE SENSORY STATION: A TWO-PART DEVICE THAT PROVIDES SENSORY STIMULATION TO PEOPLE WITH MULTIPLE DISABILITIES

Designers: Gerry Khorn, Jonathan Luna, William B. Torrey
Client Coordinator: Deborah Plumer, Coastal Connections, Amesbury, MA
Supervising Professor: Donald Rhine
Electrical and Computer Engineering Department
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INTRODUCTION

The Sensory Station (SS) is a two-part device designed to provide sensory stimulation for people with multiple handicaps (see Figure 17.15). The first device (FD) is an interactive low-resolution display that utilizes touch sensors and a microphone as user inputs. The second device (SD) is a light chase game with a slideshow containing scenic pictures. When completed, the SS was presented to Coastal Connections (CC) in Amesbury, Massachusetts.

Members of CC often show qualities of inadequate sensory stimulation. Symptoms include agitation, restlessness, and scratching. Therefore, devices that provide sensory stimulation become vital assets for everyday living. Products already in the market are excellent at providing sensory stimulation but over time they become repetitive to a user. Ultimately, the SS aims to be a unique resource of sensory stimulation by randomizing the stimulation the user can receive.

SUMMARY OF IMPACT

The design criteria for the SS were defined by the types of needs for sensory stimulation by the client. The client's main goal is to provide an environment that enables their members to make a positive contribution to their community. Without recreational sensory stimulation, members of CC will not be able perform to their full potential.

TECHNICAL DESCRIPTION

The overall structure of the SS devices were made from quarter inch thick oak wood for both stations with two quarter inch black acrylic legs secured to the sides. The purpose of the legs is to prevent the stations from being knocked down, making them almost immovable. The corners of each enclosure were smoothed off using sandpaper and the actual parts of the enclosure were fastened by inch-long brass screws.

The two stations were powered by two very similar circuits. Each circuit uses three LM317 voltage regulators, which not only provided voltage, but also the current needed to run the circuitry to power the stations. After calculating how much power would be needed to run each circuit, it was determined that the LED display would need five volts and a 1.5 ampere supply line. The LED chase game and slideshow picture frame would need both a five volt line at half an ampere, and a twelve volt line at 1.5 amperes.

The main feature of FD is the large RGB LED dot matrix display. The display is an arrangement of six 8x8 RGB LED dot matrixes, each of which is controlled by its own driver circuit. The driver circuits each contain a microcontroller and an LED driver module. The combination of a microcontroller and LED driver module allows for pulse-width modulation on every LED on the display. All of the driver circuits receive serial data from one master microcontroller. All of the driver circuits receive the same serial data and it is up to each driver circuit to determine its data in the stream.

The main purpose of the master microcontroller is to retrieve video data from a USB flash drive and user input data from sensor circuits to delegate what to transmit to the display driver circuits.

FD user inputs were capacitive touch sensors and a microphone. The capacitive touch sensors were implemented using a microcontroller to determine the discharge time of an external capacitor. When human skin makes contact with the touch sensors, the discharge time of the external capacitor changes due to added capacitance by human skin. The new discharge time is then compared to a set threshold to determine if the sensor has been activated. The microphone is also implemented via microcontroller. The microphone's function is primarily to alter the brightness of the display, which encourages voice interaction.

SD is controlled by three large push buttons that allow use of the device without fine motor skills. These push buttons also have a vibration feedback when they are pushed. One push button controls the digital picture frame that is in slide show mode with multiple calming and color rich photos. The activation of this button changes the photo.

The other part of the SD is the light chase game which consists of two rows of LEDs that are controlled by a decoder circuit and output from the microcontroller. The decoder circuit is composed of four sets of four to 16 decoders which take a number from the microcontroller and decode it to the one LED that needs to be lit. The LED color used was red and there are a total of 64 LEDs. The objective of the game is to catch the one lit LED in the outer row while the inner row is cycling. This is where the other two buttons are used to control the game. One button is used to play the game, and the other button is used to change the difficulty of the game by changing the speed at which the LEDs cycle.

The light chase game also has a large LCD in the middle of the console and this is also controlled by the microcontroller. The LCD has an 8-bit data line and three control signals and these lines are connected directly to the microcontroller. This LCD shows how close the user was before to catching the light and how many times the light was caught.

The overall cost of this project was $800.

Fig. 17.15. The Sensory Station with Client.

CAPACITIVE SWITCH CONTROLLED MUSIC STATION: PROVIDING SENSORY FEEDBACK TO ALL ABILITIES

Designers: Kevin M. McCabe, David A. Berliner, and Zachary S. Nicoll
Client Coordinator: Deborah Plumer, Coastal Connections, Inc., Amesbury, MA
Supervising Professor: Alan Rux, Senait Haileselassie, John Fairchild, and Don Clark
Electrical and Computer Engineering Department
University of Massachusetts Lowell
Lowell, MA 01854

INTRODUCTION

Capacitive Switch Controlled Music Station (CaSCoMS) was designed to provide listening control to people with various disabilities. The device is essentially a more accessible jukebox. When a button is pressed on the outside of the project, a random song from a specific genre of music will play. This device was specifically requested by Coastal Connections, Inc., a special needs daycare facility located in Amesbury, MA. The patrons at Coastal Connections could not choose music they wanted to listen to. The music system that was in place was not satisfactory. Many of the patrons at the facility cannot use a computer, a radio, or handle CDs, so the caretakers had to choose the music for them. With the coming addition of a dedicated sensory stimulation room Coastal Connections decided that it was time to improve their patron's control over the music they listened to. CaSCoMS is intended to provide ease of access to music for their patrons.

SUMMARY OF IMPACT

The CaSCoMS was effective in accomplishing its intended purpose. The ability to choose and play music was given to a majority of the patients at Coastal Connections. The project was a welcome addition to the facility's relaxation room, and is enjoyed by the staff and patients alike. The project's design was integral to making this kind of impact. The large touch-activated control buttons provide accessibility and reliability to the system. A large and strong chassis provides durability and longevity in an active environment. The CaSCoMS will be in use for a long time at Coastal Connections; others can learn from it and spread its technology to different places with similar needs as more people are exposed to this device.

Fig. 17.16. The Capacitive Switch Controlled Music Station.

TECHNICAL DESCRIPTION

The chassis was constructed from ½" plywood and ¼" LEXAN. The plywood is strong enough to endure harsh treatment, and is light enough to act as a portable device. The top rail and the door frame were made from pine. The doorframe will be under the most stress during use, so pine was selected for the construction. The button area is made of ¼" LEXAN that can withstand the force of a human slamming their fist down on a switch. The structure is held together with wood screws, wood staples and wood glue. The doorframe is reinforced by a 1" x 1/8" x 36" aluminum angle. A ¼" foam seal is used wherever the frame closes to create a tighter, safer seal. The screen was mounted on the top using two hinges and fir for support. Two catch locks were installed on the sides to keep the chassis closed. This structure provides a safe, user-friendly, and visually appealing case that the client will be pleased to have in their facility.

The most important part of the project is the way in which the user interfaces with the device. Capacitive switches accomplish this task very effectively, providing a widely accessible and easy to use solution. The IC used for the capacitive switch is the Atmel AT42QT1010. Since the human body acts as a capacitor, the touch of a user will trigger a change in capacitance of the metal plate causing the "switch" to close. When a switch is activated, a group of corresponding LEDs will light giving the user visual feedback. There are twelve capacitive switches to control the system. Two buttons control play and pause. The remaining ten buttons are assigned to 10 different genres of music. If one of these 10 switches is activated, a song from that particular genre will be played. This allows for a "one-touch and play" system which users of all abilities can enjoy.

When a person is touching a capacitive switch a voltage is sent to the PIC 18F13K50 microcontroller. Each switch has its own input terminal so that the microcontroller can easily distinguish which switch is being pushed. In order for the microcontroller to be used with a USB interface, the clocks of each device must match up. The internal clock of the PIC 18F13K50 is too slow to match the USB clock. The match is accomplished by using a 12MHz external oscillator as an external clock to the microcontroller. The PIC is programmed to use the generic "Human Interface Device" drivers for communicating with the computer. With the matched clocks and a driver, the PIC can be used to translate the voltage into something readable by the computer. The microcontroller translates the voltage from the closed capacitive switch into a joystick button press to be interpreted by the Visual Basic program. On the button press, the program will play a song and a visual effect.

The central part of CaSCoMS is the computer inside of the chassis. The signals from each capacitive switch are sent to the microcontroller, interpreted, and sent via USB to the computer. Using a Visual Basic program, the signals from the microcontroller trigger an event that plays a random song from the genre assigned to that character. The screen on the outside of the chassis will also display a visual effect.

An approximate cost of this project is $700 for the parts and materials.

Fig. 17.17. CaSCoMS with a Client.

JOYPOD: A DEVICE THAT MAPS IPOD FUNCTIONS TO JOYSTICK INPUT

Designers: Michael Moore and Joshua Northrup
Client Coordinator: Deborah Plumer, Coastal Connections, Amesbury, MA
Supervising Instructor: John Fairchild
Electrical and Computer Engineering Department
University of Massachusetts at Lowell
Lowell, MA 01854-1435

INTRODUCTION

The JoyPod was designed to provide our client with the ability to control an iPod using a joystick. The device (Figure 17.18) is comprised of a joystick for input and a microcontroller which accepts input signals from the joystick and communicates them to the iPod. When the joystick is used, the microcontroller interprets which direction it was moved in and gives the iPod the accompanying command. Upon completion, the JoyPod was presented to the client, Kevin, at Coastal Connections in Amesbury, Massachusetts. He has cerebral palsy resulting in severely diminished mobility, but maintains full mental capacity. This left Kevin unable to control his iPod on his own, forcing him to rely on others to change the volume and operate other functions. In the end, JoyPod is meant to give Kevin more independence when using his iPod music device.

SUMMARY OF IMPACT

The design for the JoyPod was based upon Kevin's needs. Given his capabilities, the best course of adapting the iPod functionality to a different human input device (HID) was a joystick. It didn't take long to see that Kevin had very good control over the joystick on his wheelchair and it became obvious he could exercise the same control over his iPod. Our major desire, and hopefully something we've achieved, is to increase his quality of life through some desired independence.

TECHNICAL DESCRIPTION

The circuit was designed around a minimalist ideology. This was done to keep the circuit as robust as possible and by correlation, limit the amount of current draw on the battery used to power the device. The circuit design can be broken down into three major sections: the regulator circuit, the logic leveler circuit, and the microcontroller with its peripheral components.

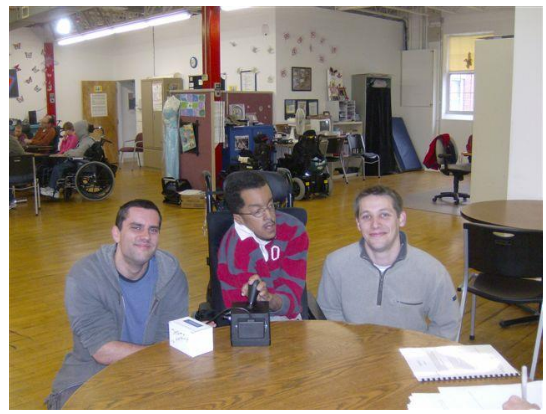

Fig. 17.18. The JoyPod.

The Maxim Max603 and Max604 adjustable, low-dropout, low quiescent current, 500 mA linear regulators were used in this project for voltage regulation because they're well suited for low to medium power battery applications. The Max603 and Max604 when used with a pair of 10 uF capacitors are capable of efficiencies closely matching those found using more complicated switching regulator designs. This is possible due to the internal 1.20 V reference, error amplifier, MOSFET driver, P-channel pass transistor, dual-mode comparator, and internal feedback voltage divider of the chips. The 1.20 V band gap reference is connected to the error amplifier's inverting input. The error amplifier compares this reference with the selected feedback voltage and amplifies the difference. The MOSFET driver reads the error signal and applies the appropriate drive to the P-channel pass transistor. If the feedback voltage is lower than the reference, the pass transistor gate is pulled lower, allowing more current to pass and increasing the output voltage. If the feedback voltage is too high, the pass transistor gate is pulled up, allowing less current to pass to the output. The output voltage is fed back through either an internal resistor voltage divider connected to the OUT pin, or an external resistor network connected to the SET pin. The dual-mode comparator examines the SET voltage and selects the feedback path used. If SET is below 80 mV, internal feedback is used and the output voltage is regulated to 5 V for the Max603 and 3.3 V for the Max604. Additional blocks also included in the Max603 and Max604 are a fold-back current limiter, reverse current protection, thermal sensor, and shutdown logic. The internal resistor voltage divider was used to establish the 5 V and 3.3 V reference voltages that were needed for the next section of the circuitry, the logic leveler circuit.

The logic leveler section of our circuit performed the task of converting the TTL (Transistor-Transistor Logic) voltage signals to the 3.3 V logic levels used by the iPod. This circuit also worked to protect the lower voltage device from any higher voltage spikes that may occur on the higher voltage end of the signal line. For this reason, we chose to use this circuit in lieu of a simple voltage divider. The circuit would also better serve serial communication from the microcontroller by being a bidirectional level shifter.

The last component of our overall circuit was the Atmel ATmega328P microcontroller. This microcontroller was used because it had sufficient memory and ports, as well as six pulse width modulation (PWM) channels, a six-channel, ten bit ADC and a Programmable Universal Synchronous, Asynchronous Receiver-Transmitter (USART). The PWM was not needed once we decided to use the Maxim regulators but initially was sought after for its use with typical switching regulator device circuits. The ADC would have been needed had we not found a joystick which allowed for our microcontroller to receive a positive 5 V fixed signal or 0 V signal. The multiple ports enabled our design to use one pin for each switch signal that could be sent by the joystick. The 32 K bytes of in-system self-programmable flash memory, 1 K bytes of EEPROM, and 2 K bytes internal SRAM allowed us to store and run the embedded software on one chip.

The microcontroller code was written with the goal of taking input from the joystick, interpreting which direction the joystick was moved in, and sending the

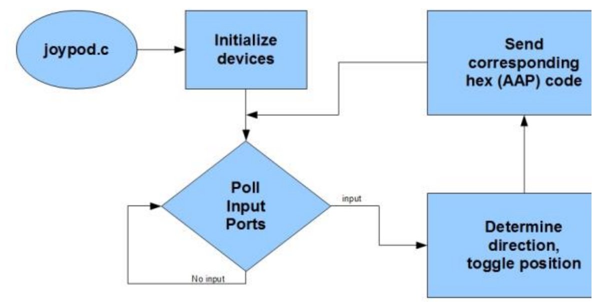

Fig. 17.19. Flowchart of microcontroller code.

corresponding command to the iPod. The flow of the program (Figure 17.19) is: 1) initialize devices, 2) checks for active input, 3) when there is an input, determine which input it is, 4) send output according to input, 5) and start again at (2). The initialization is done for both the microcontroller (setting ports as inputs and configuring USART) and the iPod (putting it in the right mode). Until an input is recognized, it continues to check all input pins for a change of state. Once the change of state takes place, the exact input is determined and the USART sends a defined hex sequence corresponding to that input. These hex sequences mimic the internal signals which are seen by the iPod when its own interface is used (e.g. scroll wheel or center button).

The enclosure for our JoyPod project needed to satisfy the following conditions: 1) must be water-proof, 2) small enough to be placed on the electric wheel-chair's arm tray, 3) able to house the joystick, embedded circuitry, and battery. An aluminum O-ring sealed enclosure was selected as the main housing for our device. We were able to mount the joystick along with a polyurethane boot to weather proof the seal. The battery was placed in the lid of the enclosure for easy access for recharging. Finally a small shroud was attached to the side of the main housing which used a rubber gasket to seal the lid and waterproof the compartment. Inside the compartment is where the dock connector board was housed. The dock connector PCB allowed our device to be used with any iPod device that accepts a dock connector. This served to make our device more user friendly for our client and not a device specifically designed for a single iPod model. The cost of parts and materials was about $150.

INTERACTIVE CAUSE-AND-EFFECT (ICE) INITIATIVE

Designers: Michael Levine and Keith Chamberlain
Client Coordinator: Patti Petterson, Bridgewell, Lynn, MA
Supervising Professor: Donn Clark
Department of Electrical and Computer Engineering
University of Massachusetts Lowell,
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Lowell, Massachusetts 01854

INTRODUCTION

The ICE Initiative is dedicated to developing a solution to an existing real-world need for cause-and-effect training. The ICE Device teaches users the result of performing an action. The ICE Device has five modes of operation. Four of the modes are games which teach cause-and-effect over varying levels of complexity and require varying levels of reasoning ability to play. A final mode of operation provides calming output sequences to put the users at ease.

The ICE Device is a system that has a central display for stimulating visual outputs. Figure 17.20 displays the ICE Device. It has a central input panel containing a center button with four directional buttons arranged around it. Each of these buttons is surrounded by lights that are capable of producing five distinct colors corresponding to various cause-and-effect stimuli initiated by the users. For each game, users are to either press or shake sensors as inputs to the device. The color of the input which a user activates is strongly correlated to the color of the output video and visuals (lights) resulting from activating the inputs. This teaches the link between activating an input of a certain color and observing an output which is related to that color. Each of the games has a different level of difficulty, but all of the games reinforce the cause-and-effect concept. The ICE Device is an improvement over current competing products because it has more sensory output capabilities, greater configurability, and more modes of operation than competing products.

SUMMARY OF IMPACT

The ICE Device was designed to satisfy the varying needs of clients at the Bridgewell care facility. The ICE Device has a user friendly input interface comprised of five large input buttons that allows those with limited motor control to easily use.

Fig. 17.20. The ICE Device.

According to occupational therapist Patti Peterson, "The device will help to motivate and encourage active and functional movement as well as promote concentration and attention." Figure 17.21 shows a picture of the ICE Device being delivered to the client.

TECHNICAL DESCRIPTION

The ICE Device uses a central computer connected to input and output subsystems to control all of the input and output hardware. This computer is a standard 32-bit personal computing system. Several PIC16F690 microcontrollers act as a bridge between the central computer and the input/output hardware. In response to the central computer's requests, the input and output subsystems sense inputs and turn on/off the devices which the

Fig. 17.21. Presenting Device to Clients.

computer addresses. In this way, the central computer has direct control over each of the input and output devices. Figure 17.22 displays the top level schematic/block diagram of how the central computer communicates with the input/output circuitry through the computer's parallel port. In response to requests from the central computer, the output microcontroller uses digital addressing circuitry to physically turn the output hardware on and off. Inverting op amp integrators are used to fade the LED's on and off slowly to prevent users from having seizures. Note that additional Buffer/Driver circuitry is present to prevent the output devices from overloading the digital addressing circuitry. Specifically, the output devices include: the light emitting diodes of assorted colors, lights, and fans (sensory output).

The input microcontroller is able to communicate input states to the central computer through the parallel port. Shake sensors (accelerometer based) and squeeze sensors (continuity switch based) are used as inputs to the ICE Device. The accelerometers in the shake sensors produce analog voltages which are proportional to the acceleration which they experience. When shaken, the accelerometers embedded in the shake devices increase their output voltages. A PIC16F690 microcontroller is used to perform analog to digital conversions of the accelerometer voltages. When the sensors are shaken and the accelerometer voltages exceed predefined values, the input subsystem notifies the central computer that a device has been shaken. The software portion of the ICE device is housed on the central computer and was written using Visual Basic 2008 which utilizes the .NET framework. This software is what constitutes the four games and the calming mode. This software initiates the communication between the central computer and the input/output subsystems. It orchestrates the synchronization of the input/output subsystems through multithreading techniques.

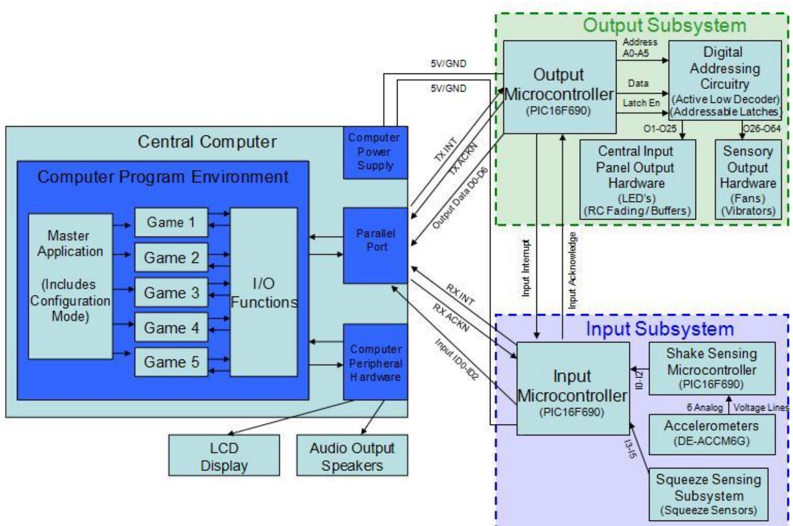

Fig. 17.22. ICE Device Top Level Schematic.

ANALOG BEAMFORMING IN A PHASED ARRAY TELESCOPE

Designers: Mihai Albu, Barton Kincaid, Richard Jackson
Client Coordinator: Barton Kincaid, Richard Jackson, MIT Haystack Observatory, Westford, MA
Supervising Professor: Jim Drew
Department of Electrical and Computer Engineering
University of Massachusetts
Lowell, MA 01886

INTRODUCTION

The Beamformer Control Board (BFC) was designed to steer a radio telescope currently being built by the Haystack Observatory. Astronomers use radio telescopes to passively detect electromagnetic waves emitted by celestial sources. An antenna array is currently being built in Western Australia that will operate in the 80-300MHz frequency band. At this frequency range, the radio waves are able to penetrate the atmosphere with very little distortion allowing for an unprecedented look at the universe. This array will sum the signals from multiple smaller receptors, or tiles, instead of observing with a single large antenna. As the tiles and dipoles have no moving parts, delays must be used to steer the array in order to observe a particular source. The analog beamformer is the component which receives dual polarization signals from all 16 dipoles in a tile and applies independent delays to each signal to form a tile beam.

Such a design has become attractive due to the recent availability of high performance electronics at a lower cost. In order to achieve comparable sensitivity to single aperture designs, more telescope tiles must be added, for a total of 512 tiles and BFCs when the array is completed.

SUMMARY OF IMPACT

The primary design objective required to achieve the beamforming operation is to develop a method to shift and latch the data stream received from the central node without the use of a continuously running clock. The clock lines between the node and BFC are active only during switching operations which ensures that radio frequency interference generated by the beamformer electronics is minimized. The requirement of a radio quiet environment is crucial to the performance of the telescope in the relatively unexplored 80-300MHz frequency band.

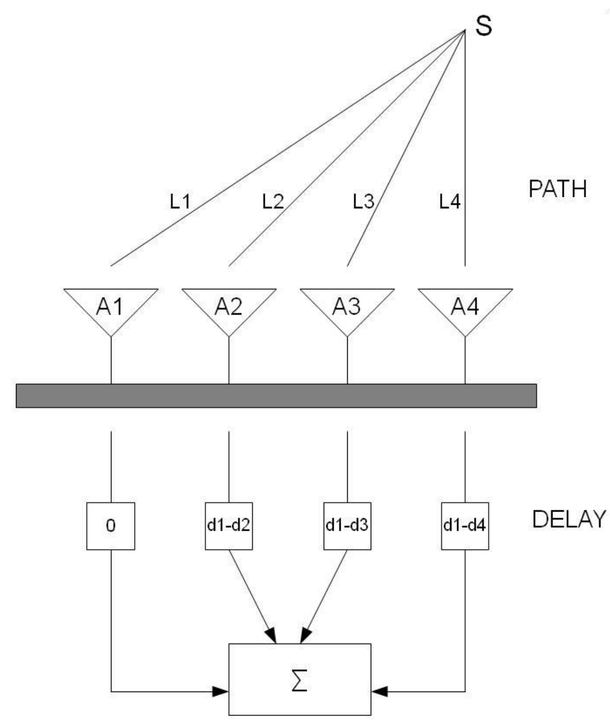

Fig. 17.23. Tile Layout.

TECHNICAL DESCRIPTION

The analog beamformer is composed of five delay lines for each dipole and a BFC. Each delay may be switched in and out of the signal path by the BFC via two ganged single pull double throw (SPDT) switches.

At the heart of the BFC is a Xilinx complex programmable logic device (CPLD). The CPLD is connected to 8-bit serial in parallel out shift registers (SIPO) which are wired serially so that the entire 192 bit switch stream can be shifted through all 24 SIPOs.

Fig. 17.24. The Xilinx XC256 CPLD.

Once the entire stream is shifted in, the CPLD latches all data bits which drive the SPDT switches.

The CPLD is programmed with Verilog, a hardware definition language, to function as a state machine. As the CPLD has no internal clock, one is provided by the node. In order to wake the BFC circuit, the node transmits a unique header that signifies the start of switching data. This brings the CPLD into an idle state. Upon receiving this header, the CPLD enters the packet state and waits to receive 16 switching bits. The CPLD passes the node clock as a register clock to each individual SIPO. After receiving 16 bits, the CPLD switches into the wait state to check whether it has received all 192 bits and switches back to the packet state if it has not. This process will continue until all 192 bits are shifted into the 24 8-bit SIPOs, after which the CPLD enters a checksum state and waits for the checksum to be received from the node. If the internally calculated and received checksums are identical, the CPLD latches the 192 bit switch stream into the output register of the SIPOs which drives the appropriate SPDTs. Any discrepancy between the two checksums signals a channel error between the node and BFC and is flagged and transmitted back to the node. The CPLD will then revert back into its idle state. The Xilinx CPLD was chosen after initial tests confirmed that it can be initialized in a known state upon the reapplication of a clock.

Fig. 17.25. Delivering the completed beamformer controller.

Manufacturing/Component Cost: $1445.95

THE ONETOUCH JUKEBOX: AN AUDIO AND VISUAL PLAYBACK DEVICE FOR USERS WITH LIMITED DEXTERITY AND COGNITION

Designers: Scott Wilson and Nichole Griffin
Client Coordinator: Patti Petersen, Bridgewell Day Services, Melrose, MA
Supervising Professor: John Fairchild
Department of Electrical and Computer Engineering
University of Massachusetts Lowell
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Lowell, Massachusetts 01854

INTRODUCTION

The OneTouch Jukebox (OTJ) is an audio and video playback device designed specifically to meet the needs of high-functioning disabled adults at the Bridgewell Day Services Melrose, MA location. The location in which this device was implemented has a population of disabled individuals who are very enthusiastic about music and were delighted to have such a device as a part of their day center. Designed to be simple and easy to use, the OTJ is based around a Windows desktop running custom software, a touchscreen interface, and external pushbuttons to provide users with a simple and intuitive means for interacting with the device. This design approach was taken as a way to simplify the use of a personal computer for users with low or moderate motor function disabilities. Current solutions on the market do not provide a simplified or cost-efficient user interface that the OTJ does. The OTJ is displayed in Figure 17.26.

SUMMARY OF IMPACT

Since delivering the OTJ to Bridgewell Day Services, the users have all had a very positive response to the device. Once individual profiles had been set up on the device, the user interface allowed each person to control the device simply using the three external pushbuttons. Additionally, users have been up and moving around more since receiving the device. The OTJ design has proven to encourage active behavior and social interaction.

TECHNICAL DESCRIPTION

The OneTouch Jukebox is designed to use a stand-alone computer system as a host for a Windows-based graphical user interface (GUI) application. Incorporating a 17" touch-screen display along with

Fig. 17.26. The OTJ.

external pushbutton switches provides the two means of controlling the device. An MCU-based control circuit is used to communicate to the host application when any of the pushbuttons are actuated. Users are able to upload media content directly to the device via USB. A simple user interface allows users to play music with a single touch or push of a button.

The software running on the device is capable of handling multiple hardware inputs, storing user information and data, as well as controlling audio playback and visual media. The key background features of this software include multi-threaded execution, hierarchical file-path organization and system-state logic. Multi-threading is used to handle simultaneous tasks, such as audio playback, visual display and input polling. File paths for user content are written to a "master list" XML file to be accessed for easy-loading of stored media every time a profile is selected. A software state-machine is use for seamless operation. For instance, if a user chooses to pause audio playback and return to the main menu, the system state is stored in the event that the user returns to the same profile to resume playback. If the user chooses a new profile, a new system state is initiated. The front end of the software, as seen in Figure 17.27, is simply designed with ease-of-use and versatility in mind.

The total cost of implementing this design was approximately $600.

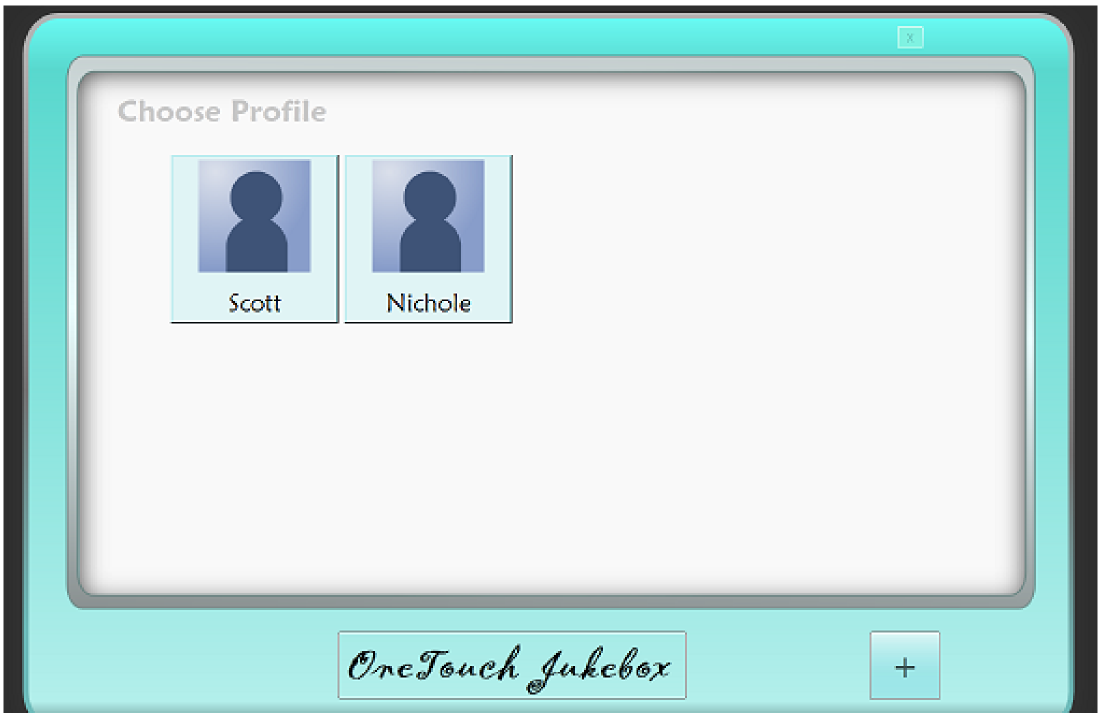


Fig. 17.27. Front End of the Software.

THE WRIGHT WHEELCHAIR: MODIFYING A MANUAL WHEELCHAIR TO PROVIDE PROXIMITY DETECTION AND FEEDBACK TO ANY USER.

Designers: Stephen C. Wright
Client : Student from UMass Lowell
Supervising Professors: Jim Drew
Electrical and Computer Engineering Department
University Of Massachusetts, Lowell,
Lowell, MA 01854

INTRODUCTION

The client of this design uses a manual wheelchair, and is blind. He requested a design that could prevent him from bumping into walls and objects when traveling around Campus. This was the project's main objective; design some kind of warning for the user when approaching obstacles. Multiple sensors are used to trigger vibration motors if a certain distance to an object is reached. Other designs similar to this have only been done for automatic wheel chairs. The Wright Wheelchair intends to enhance our client's level of independence, and allow him more personal interaction with his environment.

SUMMARY OF IMPACT

The design criteria's for The Wright Wheelchair were defined by the very needs of our client. He explained that without a system like this, he is solely reliant on others to guide him. What the client likes most about this design is, once the system is turned on, it can immediately begin giving proximity detection feedback! The Wright Wheelchair also encourages our client to use the system and try navigating about on his own. This design works well but it does have a learning curve. All new users would need to adjust to the sensitivity of the design.

TECHNICAL DESCRIPTION

The circuitry for the design fits onto a 4"x4" board and is stored, along with the battery, underneath the client's wheelchair. Two sensors, one sonar and one infrared are orientated for detection on both left and right sides. The infrared sensor outputs an analog signal and the sonar outputs over the I-Squared-C Bus. A rechargeable lithium-ion battery powers the system and this battery was selected to assure that it would last our client an entire day. In the end, four sensors, two vibrating motors, one dc to dc converter, two peripheral IC drivers, one Lithium ion battery, and two microprocessors were needed to create The Wright Wheelchair. The approximate cost for the entire design was $600.

Fig. 17.28. The Wright Wheelchair.

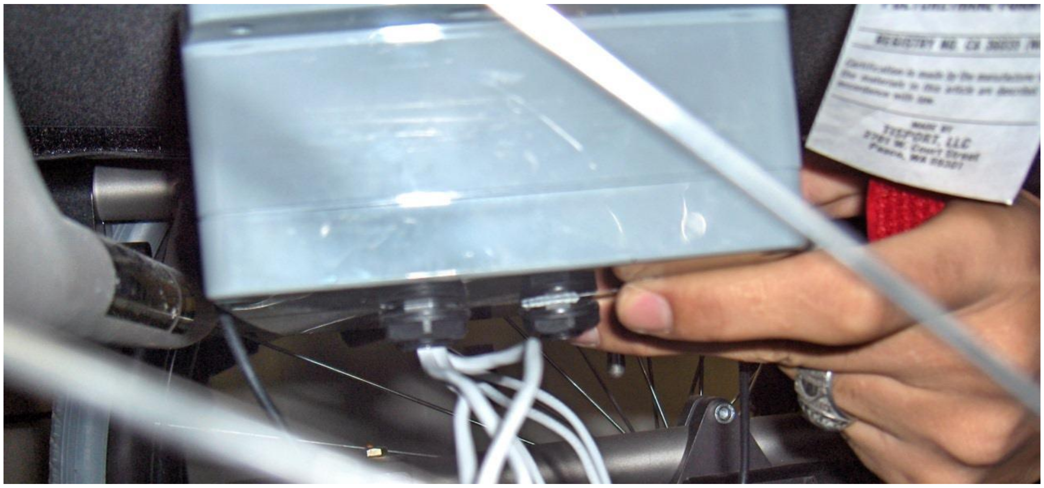


Fig. 17.29. Screen for Device.

SENSORY INTERACTIVE BOARD: A DEVICE FOR SENSORY ENTERTAINMENT FOR STUDENTS WITH DISABILITIES.

Designers: Woodlyne Daniel and Merrytime Ebhohon
Client Coordinator: Patti Peterson, Bridgewell Rehabilitation Center, 162 Boston St. Lynn MA
Supervising Professors: John Fairchild
Electrical and Computer Engineering Department
University of Massachusetts Lowell
1 University Ave. Lowell, MA 01854

INTRODUCTION

The Sensory Interactive Board that is designed for clients with mild to severe developmental and physical disabilities to initiate videos of their favorite scenes and or listen to music. Bridgewell's Day Rehabilitation Center in Lynn, MA provides several activities which includes an activity room with a mat used for relaxation by some students. While the patient stretches their muscles the only component missing at the center was an interactive board. The center offers various types of supports to students from 17 years old and up. During its 50 years of existence, the staff members are committed to satisfy their patients/students on a daily basis. The agency is also known for connecting people with possibilities and this is our chance to get connected with them. Lying on one's side for a long time causes several discomforts. By lying on the Sensory Interactive Board the clients are able to place their leg on the sensor at will which triggers images and or music to play.

SUMMARY OF IMPACT

The main objective of the project was to design an interactive sensory entertainment board for patients with mental disabilities and prone to seizure. The device displays various images of ocean, tropical and aquarium scenes accompanied by classical music. The client select scenes and music that best help them relax, but also keep them motivated and active while lying on the mat. The interactive board encourages the client to move rather than lay on the mat without doing anything for a long period of time. The device is easy to use and gives the client total control of the system. Being in control is something that many students with disability lack since most things are done by their caregiver. In addition, the device also stimulates client's visual and auditory senses while they watch the display.

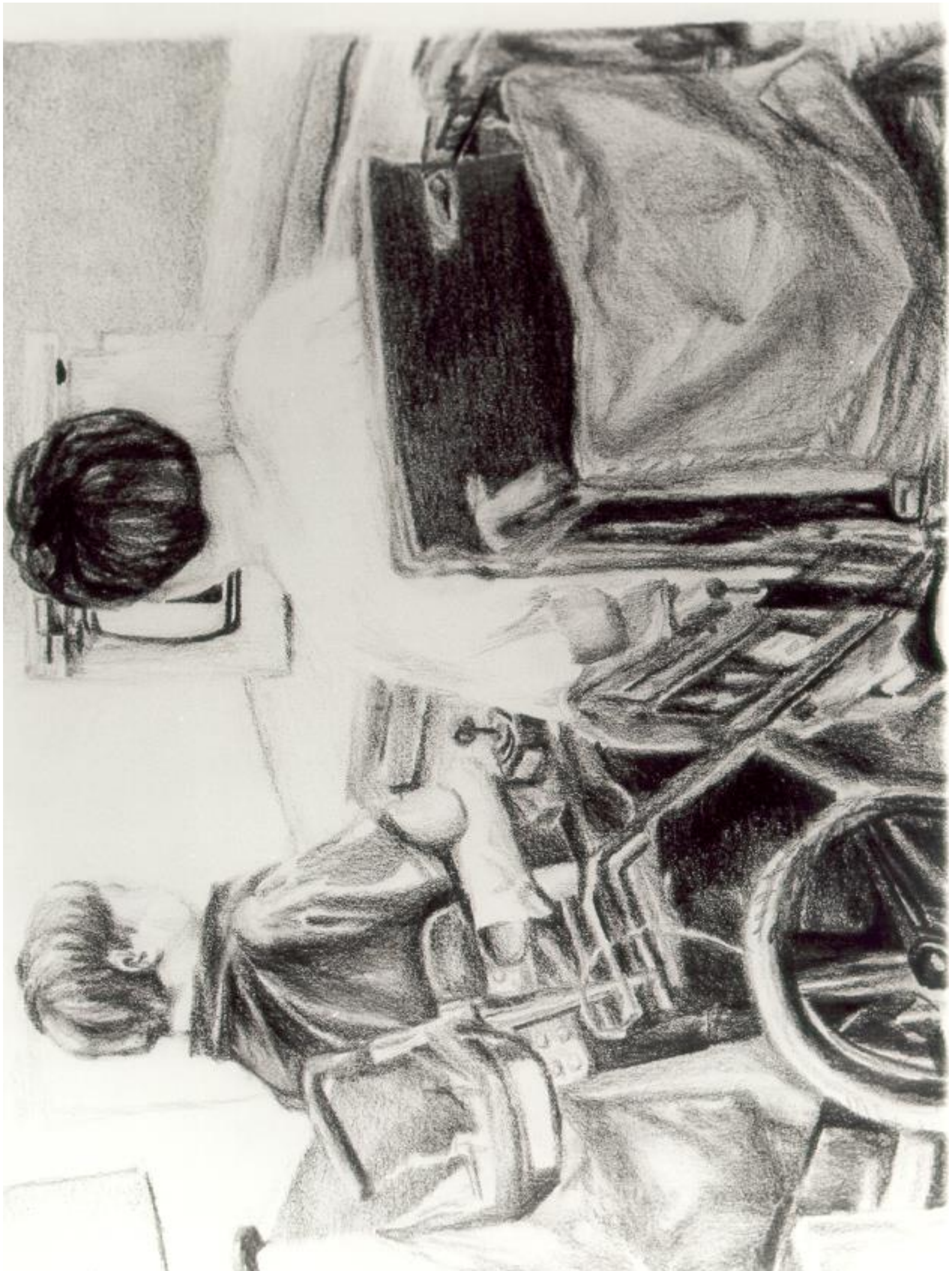
TECHNICAL DESCRIPTION

The overall structure includes a board, pad, and control box. The control box is made from a sheet metal box measuring 4" x 6". The overall circuitry is enclosed in the box and the power plug outlet, serial port, and sensor switch are all connected and mounted outside of the box. Along with the visuals and audio responses, the client also receives a computer since the program is stored directly on the computer with Visual Studio software. The touch sensor is made using a capacitive touch sensor QT113 and programed to a microcontroller chip that sends a message to the computer through a 9 - pin serial port when movement is detected. The control box is powered with a 9 VDC battery which is attached to an LM7805 voltage regulator that would reduce it to a 5 VDC which is what is needed for the microcontroller and sensor chip to work correctly.

The box was set to run with batteries and, once it is powered on, the client can then press the switch which is connected to a universal jack. This enables the client or the caregiver to change the switch as they wish.

The total cost of parts/material was about $82.87 with a PC and Monitor donated by the ECE department.

Fig. 17.30. Sensory Interactive Board.



CHAPTER 18
UNIVERSITY OF MICHIGAN

College of Engineering
Department of Mechanical Engineering
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Principal Investigator:

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PILL DISPENSER WITH VIDEO RECORDING

Designers: Jim Haberer, Jasdeep Khabra, and Mark Sprague
Supervising Professor: Dr. Albert Shih
Department of Mechanical Engineering
2350 Hayward St.
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INTRODUCTION

The task is to develop a pill dispenser for Alzheimer's patients to assist them in taking the correct medication at the correct time including "as-needed" medication and, more importantly, confirming for their loved ones and caretakers that the medication was taken properly. If we succeed, the experience will give more freedom and peace of mind to the patient, caretaker, and family members that the medication was taken properly. The team has developed a device which accomplishes this goal.

Because there are a number of devices on the market which handle scheduled medications quite well, the team decided to purchase such a device and implement a webcam rather than fabricating our own. This device has 28 compartments and up to four alarms per day. When the alarm sounds, the appropriate medication is rotated into place. All other medication is protected, allowing only the appropriate medication to be taken. When the user turns off the alarm, the webcam on a Dell netbook will be triggered. There is not a presence of "as needed" dispensers for home use, so the team has fabricated an "as-needed" device. Both the scheduled and "as-needed" devices have been set up to communicate with the webcam on the netbook to record, save, and send the video file. The "as-needed" device operates in a similar fashion to the scheduled device. A circular tray contains 12 compartments, each of which will contain one dose of medication. The lid is clear to allow the user to view the entire contents. Only one compartment is accessible at a time, and the lid locks, restricting access to all other compartments.

SUMMARY OF IMPACT

Upon completion of the prototype, the team took the device to Coffeehouse, a mild memory-loss support group at the Turner Senior Resource Center, where they had originally visited. Here they developed customer requirements and engineering specifications and received validation that the device was useful from the perspective of potential users. In summary, those surveyed felt generally safe using the device and that the device met their medication regimen needs.

Fig. 18.1. "As-Needed" Medication Dispenser.

Lastly, the team took the prototype to the Michigan Alzheimer's Disease Center (MADC) to obtain additional validation from the perspective of doctors and health care professionals. Notable people from the group included the MADC Director Hank Paulson, MD, Ph.D; the MADC Dementia Care Advisor Nancy Barbas, MD, MSW; and an Adjunct Assistant Professor from the Department of Neurology Hiroko Dodge, Ph.D. Similarly to Coffeehouse, this group of eight professionals generally felt that those with memory loss would feel safe using the device and that it would meet their needs.

TECHNICAL DESCIPTION

The "as-needed" device consists of a rotating tray with 12 compartments. There is a transparent top that allows the user and caretaker to see how many pills are in the device at any given time. The device is slightly over six inches in diameter and about three inches tall. There is one opening that allows for access to one compartment at a time. When a user desires a pill, they press a button to indicate they would like a dose of the as needed medication. The device will unlock if conditions are correct for the user to take a dose. The top locks to prevent access without the use of a key. The design allows for 11 doses of medication to be loaded into the device at a time. This decision was due to space configurations and the need to hold many different sized pills. The team decided that the device should be no more than 6 inches in diameter in order to fit well on a counter top. The team also felt the device should be able to hold pills up to 20mm in length. Thus, the device was limited to 12 compartments. As one compartment must be empty when the device is loaded, the capacity is eleven doses. The design could be easily modified if needed to provide for more compartments to hold medication; however, the device would grow significantly larger as more capacity is added. If the device is taken to market, two variants could be offered, as the capacity versus space issue is very dependent on the individual customer and no universal answer exists. The team chose to make the tray 6.25 inches in diameter. This dimension was chosen to fit nicely inside the outer shell case. The team chose for the inner diameter of the tray to be 4 inches. This allows each slot in the tray to have a radial depth of 1 inch, allowing for even the largest of pills to fit.

The team strived to design the device to not utilize a motor. The team chose to design a system that lets the user advance the tray manually. The system restricts motion when the device is locked and prevents the user from rotating the tray backwards or too far. The mechanism uses a series of slots in the bottom of the tray and two solenoids, which default to the extended position. When the device is locked, one solenoid is at each end of the engaged slot, which restricts motion in each direction. The overall rotation in the tray is detected using a system of micro switches and raised bumps on the bottom of the tray.

The project cost approximately $597.

DEVELOPMENT OF A DOG EXERCISE DEVICE FOR USE BY ELDERLY PEOPLE AND THE WORKING-CLASS

Designers: Heather Dorer, Florian Baier, Jinhyung Hwang, and Jill Rodriguez.
Supervising Professor: Dr. Albert Shih
Department of Mechanical Engineering
2350 Hayward St.
Ann Arbor, MI 48109

INTRODUCTION

While many people experiencing memory loss are encouraged to own a dog, often times they are unable to take care of one. Therefore, our project sponsor Cassie Starback, from the Alzheimer's Disease Center, prompted the design problem of developing a device to assist people experiencing memory loss who still live independently to take care of their dogs. Not only would this preserve companionship between the owner and the dog, but it would also prevent the premature surrendering of dogs to animal shelters.

SUMMARY OF IMPACT

The Michigan Alzheimer's Disease Center (MADC), founded in 1989, studies patients with Alzheimer's disease and other cognitive impairment disorders, and strives to educate the community on these diseases. Their interaction with Alzheimer's patients for over two decades has identified the countless struggles these patients face due to forgetfulness while performing menial tasks such as taking pills, cooking, and caring for their pets. The dwindling ability of patients to perform tasks that they were once able to perform then causes these patients to become frustrated and have lower self-esteem. As the MADC strives to expand the quality of life for people with Alzheimer's disease, they encourage the development of technology that will allow them to live as independently and comfortably as possible.

One contributor to the quality of life for people with Alzheimer's disease is pet ownership. While people with memory loss are encouraged to have a dog, they frequently forget to care for it and have to surrender it to an animal shelter as a result. In an effort to expand the quality of life for these patients, the MADC has requested that our team develop an exercise device for dogs that requires minimal human interaction. This device would encourage people in the early stages of memory loss to keep their dogs and would allow them to care for their pet by themselves.

Fig. 18.2. Dog Exercise Device with Treat Dispenser.

TECHNICAL DESCRIPTION

The device has two main mechanisms: the ball launcher and the treat dispenser. The following steps describe the function and use of the two mechanisms.

The Ball Launcher

1. Load ball into device by placing it in the launching tube.

2. Once the ball has rested in the basket, a snap-action sensor will trigger the motor to start.

3. When the motor starts, a series of gears will rotate a power screw, allowing the sliding mechanism to pull the basket back from its resting position, which is at the top of the launching tube behind the basket.

4. While the basket is being pulled back, the tension springs will be stretched.

5. As soon as the latch, which pulls the basket back via the sliding mechanism, hits the trigger, the springs will pull the basket forward. At the same time, the trigger will hit a snap-action switch at the end of the track.

6. The ball then flies forward as the basket reaches the end of its track.

7. After hitting the snap-action switch at the end of the track is engaged, the motor will then move forward in the tube.

8. The slider will then hit a snap-action switch at the top of the track, which will stop the motor. At this time the latch should be engaged with the basket, and the device is ready to be loaded again.

The Treat Dispenser

1. While the carriage is being returned to its resting position, the bolt on the back of the carriage will hit the rubber flap in the forward direction.

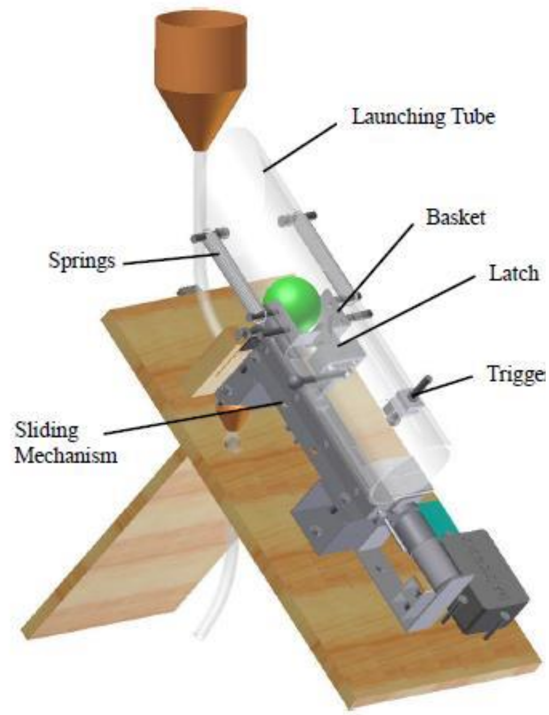

Fig.18.3. Schematic of Ball Launcher.

2. When the rubber flap is hit by the bolt in this direction, it will move the wooden flap, releasing a treat.

3. The treat will fall into the secondary dispensing tube, which will direct the treats towards the front of the device for easier access for the dog.

4. Note that when the basket is being pulled back, hitting the rubber flab will not release a treat

The total cost for this project was $171.

A PORTABLE REMINDER DEVICE

Designers: Ben Hubbard, Mark Vossler, and Austin Salgat
Supervising Professor: Dr. Albert Shih
Department of Mechanical Engineering
2350 Hayward St.
Ann Arbor, MI 48109

INTRODUCTION

The goal of this project is to design and manufacture a portable reminder device that will help compensate for memory loss. Individuals with mild cognitive impairment (MCI) and Alzheimer's live with significant challenges to daily life tasks because of memory loss. This device was designed so that an individual with mild cognitive impairment (MCI) or early stages of Alzheimer's can use it by simplifying the process to as few steps as possible. The device uses buttons, a microphone, a speaker and a screen with an Arduino Mega controller to record and play back voice messages at a set date and time. This device could be used to help compensate for some memory loss, which would thus relieve some of the burden on caretakers and improve the independence and quality of life of individuals with MCI. However, according to the principles of universal design, the scope of the project could include almost any potential user.

SUMMARY OF IMPACT

Development for the reminder device focused on proof of concept. This means that the current prototype demonstrates the usefulness of this device, and allows for future investment into the idea. Limitations including budget and time constrained what could be developed, and options for future revisions should consider all possibilities, including a color screen, different button types, button layout, size, menu system, etc. Further research is needed to make these determinations and is recommended.

TECHNICAL DESCRIPTION

The cases were ordered online and then modified to hold the electrical components. Custom holes were cut in the case to hold the screen and buttons as well as to allow wires to pass through. This process was done using a milling machine and hand drill.

For the electrical assembly, many of the parts were selected to be modularized for their ease of integration into the circuit during manufacturing.

Fig. 18.4. Prototype Portable Reminder Device.

The assembly of electrical component connections is organized into inputs, outputs, controls and peripherals, which are all connected to the stackable header. The peripherals include the real time clock, which works even when the device is off, and an SD Card, which was connected to the microSD Shield. The controller is the Arduino microcontroller which was also connected to a power supply. The inputs, such as the buttons, protoboard and sound sensor send signals in and the outputs, send signals out from the LCD screen and the speaker, which must first pass through the Digital- Analog Converter. The electrical components were assembled on a breadboard in the Mechatronics workshop. For the final production design the circuit should be made on a PCB circuit-board. The prototype schematic only shows additional wiring not already present on each module purchased. Four main sections of the prototype exist, the inputs, outputs, peripherals and controller. The Arduino acts as the controller for all other devices. It takes in the inputs, the buttons and microphone audio input, and uses the peripherals, the SD card and Real Time Clock, to create the appropriate output for the device, the LCD and speaker.

The total cost of this project was $191.68

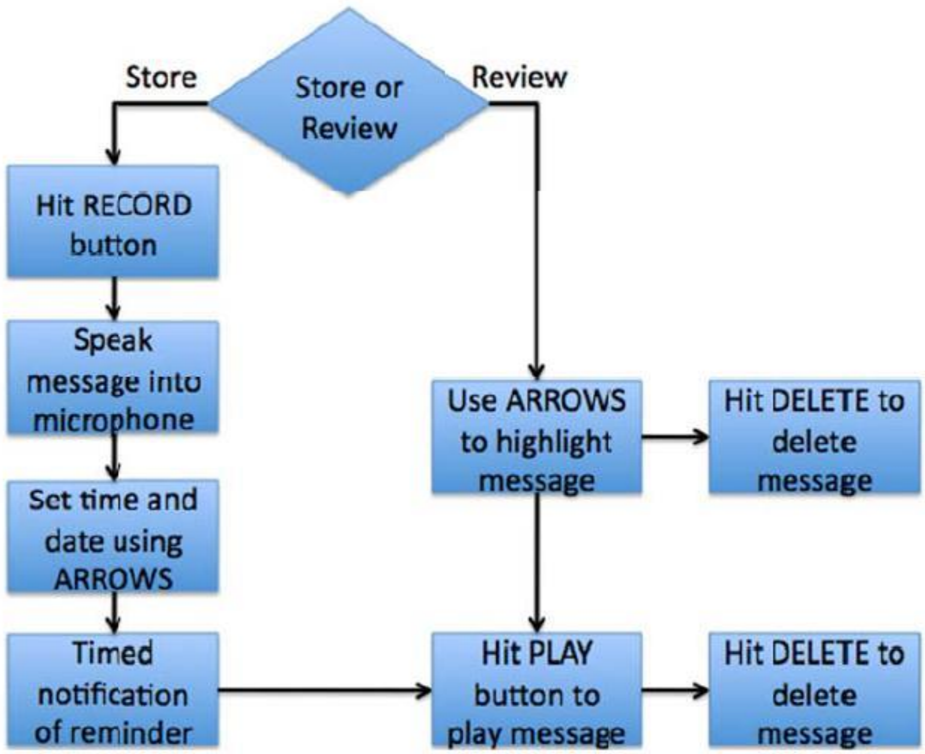

Fig. 18.5. Block Diagram of Reminder Program.

TRANSPORTABLE WHEELCHAIR SCREW-LIFT SYSTEM

Designers: Sam Beckett, Peter Gibbs, Demetri Golematis, Roger Potter
Supervising Professor: Dr. Albert Shih
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INTRODUCTION

Transferring from a wheelchair to another seat at a higher level can be very difficult for the physically disabled. Professor Albert Shih and Mr. Steve Sarns of NuStep have co-sponsored this project to design a mechanical lift called the Transportable Wheelchair Screw-Lift System (TWSS). The lift will safely raise and lower the wheelchair, easing transfer to and from the wheelchair. The lift also allows people in wheelchairs to reach higher locations that would otherwise be unavailable, thereby increasing independence and reducing the need for assistance.

SUMMARY OF IMPACT

The primary driving force behind the TWSS was the difficulty for the elderly to transfer from a wheelchair to another seat. It can be rather strenuous or difficult to make this transfer, but this difficulty increases greatly when the seats are at significantly different heights relative to each other. A self-operable lift system would not only greatly reduce these difficulties by matching the height of the target seat, but generally allow for better utilization of home spaces. This is accomplished by enabling people restricted to wheelchairs to access higher shelves and storage without the need of a clumsy reaching tool.

TECHNICAL DESCRIPTION

The main support system of the TWSS will be a 0.125 inch steel plate. The plate includes a 7.5 inch wide by 17 inch long and approximately 1.5 inch tall exaggerated U shape in the center with the excess material acting as a flange protruding from the top of the "U". To prevent the TWSS from tipping over, four legs were added to the system. The legs are 14 gauge 1 ¾ inch square stock that extends from the flange of the baseplate. The front two legs extend 9 inches straight out from the flanges and the back two legs extend straight back 6.5 inches and then turn 90° and extend outward 6.5 inches to provide adequate stability for the wheelchair. This leg design prevents the device from tipping even under a worst case loading scenario. The dimensions of the U shape in the plate are made to allow for a turntable to be placed inside and to freely rotate 360°. The turntable is 6.5 inches long, 4.5 inches wide, 1.5 inches tall. It was bolted to the baseplate and bolted to a plate that has the outermost screw welded to it at the top. This allows for the lifting mechanism on top to rotate freely. The turntable has a load capacity of 1500 pounds which well exceeds the weight of the system including the wheelchair and the dynamic load of the user.

The U shape is much longer than it is wide to allow room for the gearbox, motor, and batteries necessary to drive the system. The motor chosen is a 24 V Dewalt Drill motor complete with a Dewalt Drill Motor Gearbox. To power this motor, two 12 V, 5 Ahr Werker batteries will be connected in series to provide the 24 V needed. The motor will drive the screw system via a #40 chain and sprocket. This sprocket and chain will mate with a second sprocket located on top of the turntable. This second sprocket will be attached to the outermost component of the screw drive. The screw drive consists of steel pipes and ductile iron collars. The centermost piece, the lead screw, is 9 inches long by 1.5 inches in diameter. This rod will be threaded with standard 60° threads at a pitch of 6 threads per inch. These threads will mesh with threads put internally into a ductile iron collar. This ductile iron collar will be 2 inches tall with an outer diameter of 2.3 inches, providing 12 engaged threads at all times. The next pipe will be only 8 inches long have a 0.125 inch ledge two inches deep bored into the inner diameter to allow a proper seating for the ductile iron collar. Once the collar is seated inside of the pipe, the top edges will be welded together to provide a strong bond between the two parts. The outer diameter of the second pipe will then be threaded with 60° threads at a pitch of 6 threads per inch. These threads will mesh with the inner diameter of the second ductile iron collar. As with the first collar, this will also be two inches tall providing 12 engaged threads. The third pipe of the system will also be 8 inches long with a 0.125 inch ledge machined into the inner diameter 2 inches deep. This will allow for the second collar to seat properly inside and be welded securely. A fourth and final screw will also be 8 inches long with a 0.125 inch ledge machined into the inner diameter 2 inches deep. This will allow for the third collar to seat properly inside and be welded securely.

To prevent the system from rotating the user in the wheelchair, a casing is placed in the center around the screw lift. The casing is made of four pieces of sheet metal bent into a square with the top bent inward and the bottom bent outward so that segments cannot extend and come out of the others. This case will provide forces to resist the rotation of the wheelchair to keep the screws moving upward as well as encase the screws so that people cannot get injured by their rotation or get things caught in the screws. When the system is engaged, the sprocket and chain turn the outer cylinder. The cylinder will turn freely on the turntable, engage the threads and causing the middle and drive screws to rotate together. A stopper has been added to both the second and lead screw. When the stopper on the middle pipe reaches the ductile iron collar, it will cause the outermost and the middle screws to turn in unison, thus driving the next most inner screw upwards until its stopper becomes in contact with the top of the screw and thus drives the lead screw upwards. Once the stopper on the lead screw reaches the ductile iron collar the system will be fully extended.

The total cost for this project is $680.50

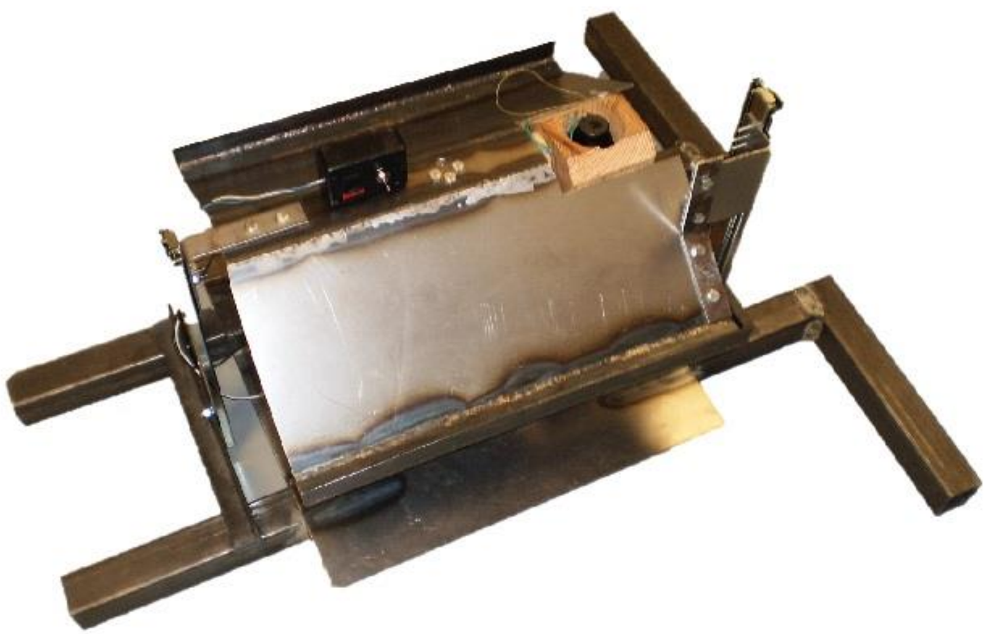

Fig. 18.6. Transportable Wheelchair Screw-Lift Prototype System.

RECONFIGURABLE PORTABLE DEVICE HOLDER

Designers: Matt Bekken, Derek Blakeslee, Kyle Harp, TJ Short
Supervising Professor: Dr. Albert Shih
Department of Mechanical Engineering
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INTRODUCTION

The goal of this project is to incorporate portable electronic devices into exercising on the NuStep T5 recumbent cross trainers by designing a reconfigurable holder that can safely secure and charge different portable devices, with a focus on tablets. The holder needs to be adjustable in 3D space to allow for the best height and orientation to interact with users and should be reconfigurable for current and future portable devices. The holder design needs to be novel, aesthetic and easy-to use, particularly for patients with disabilities.

Fig. 18.7. Reconfigurable Portable Device Holder Prototype.

SUMMARY OF IMPACT

The main owners of NuStep machines are rehabilitation clinics and people who want to continue their rehabilitation at home. The main users are people with disabilities or injuries, although not all clients have a disability. Depending on the use, time spent on the machine is anywhere from 5 to 10 minutes for physical therapy and up to 1 hour for personal exercise. The typical work out time is 30-45 minutes and some users, for example those who are rehabilitating, will work out daily or multiple times a week. Overall, users spend a considerable amount of time on the machine, which creates a need for entertainment to combat boredom and complacency. Steve Sarns, the Vice President at NuStep and our sponsor, has asked us to design a portable device holder that would allow the user to interact with their portable device. This would help to entertain and energize the user during extended workouts. The ability to interact with a portable device, like an iPad, Kindle, or iPhone, would make working out more enjoyable and help to pass the time.

TECHNICAL DESCRIPTION

The holder mechanism attaches to the NuStep machine behind the center console with a steel plate bolted to the frame. This ensures the mechanism is sturdy as it is rigidly attached to the rest of the NuStep machine. To achieve a wide range of motion in the y- and z-directions, both a locking hinge and a flexible arm are used, connected with a small steel plate. We considered using a sliding arm in the z-direction in place of the hinge, but this makes the design bulkier and more difficult to manufacture without giving a significant increase in the range of motion. Using a hinge does couple the y- and z-directions, but the flexibility of the arm allows for precise placement to view the portable device. The holder assembly uses a gear and torsion spring coupled with a rack and pinion setup to clamp on the device firmly so it does not fall out. This mechanism also allows for the sliding arms to be moved together with one hand, making setup simpler. The space between the grippers can be between 4 inches and 10 inches to hold devices from an iPod to an iPad. Since the holder should be lightweight due to limitations in flexible arm strength, the casing is made of lightweight plastics and acrylics, and excess plastic can easily be removed through milling to reduce weight further. The gears are nylon since they are strong enough and lighter than steel gears. The grippers will have slots cut out for headphone and charging cords, as well as to lower the weight of the holder overall. The gear rack is driven by a combination of three spur gears. The larger, upper, gear is driven by the torsion spring and drives the lower spur gear. This spur gear is fixed on a shaft that transfers its torque to the spur pinion gear on the other side of the holder. This pinion gear then transfers its torque to the rack gears which clamp the device. Energy is then stored into the system when the arms are opened by the user.

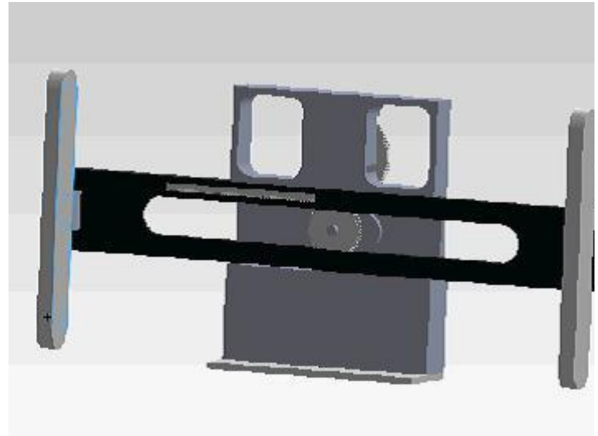

Fig. 18.8. Close-up view of Sliding Arms.

The total cost for this project is $141.77

SHEAR TEST OF A DIABETIC INSOLE

Designers: Heng Lu, Mohammed Noor Pandit, Xinrong You
Supervising Professor: Dr. Albert Shih
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INTRODUCTION

The project's objective is to develop a machine that would be able to measure the shear stiffness on the forefoot region of a diabetic insole manufactured by Michigan Diabetes Research and Training Center. Diabetic patients have high pressure and shear points in their forefoot which may lead to foot ulcers. This insole, made of neoprene rubber and a silicone layer, has been known to reduce the shear forces under the foot; however it hasn't been proven quantitatively. The project outcome would be to quantify the effectiveness of this type of sole in decreasing the shear forces under the foot. The project is sponsored by Dr. James Wrobel and Mr. Peethambran Ammanath.

SUMMARY OF IMPACT

The motivation behind this project is to develop a testing machine that would be able to determine the shear forces and stiffness on and of a diabetic shoe sole, designed by Michigan Diabetes Research and Training Center, when it is worn by a diabetic patient. This shoe sole, called the Dynamic Foot Orthosis (DFO), is a multi-layered sole designed to reduce sliding friction and torque at the metatarsal heads in addition to decreasing compressive forces that is accomplished by the conventional foot orthosis. It is designed with a rolling mechanism and addresses the friction element by accommodating the normal sliding and rolling motion at the distal 3rd of the foot during gait. DFO has a silicone layer at the metatarsal head and the remainder of the anterior section made of 2 separated orthotic layers that slide over each other. Even though this type of shoe sole has been successful in the prevention and treatment of diabetes-related foot ulcer (DFU), there has not been any quantitative evidence that can justify the above statement. The test machine will therefore measure the changes in shear forces and pressure along with the compression stiffness of the new sole.

Fig. 18.9. Shear Test of Diabetic Insole Prototype.

TECHNICAL DESCRIPTION

The final design consists of the following components:

1. Machined weights made up of carbon steel

2. C clamps attached to the heel of the insole

3. Steel tubes that support the weight and also add weight of its own

4. Aluminum Plate that acts as a ground

5. Connectors made up of carbon steel along with small steel plates supporting weight and tubes

6. Small circular steel pieces representing high pressure areas on the insole, more specifically at the toe, 1st and 2nd metatarsal and 3rd, 4th and 5th Metatarsal

7. Plywood Support Structure

8. Linear electric actuators and Kistler force dynamometers

9. Insole and shoe

A very large weight quantity of about 70kg is also exerted on the heel of the foot. Making machined weights of 70kg is unreasonable and therefore C clamps would be used to exert that force on the heel. A force dynamometer that measures force in only one direction will be used to measure the appropriate force applied at the heel. In order to manufacture weights, our team decided to use a general purpose low carbon steel material. This is because it is relatively cheap and easy to machine and has a high density of about 7850 kg-m-3. We decided to manufacture three 10kg weights, two 5kg weights, two 2kg weights and one 1kg weight. The shape of the weight will be almost cylindrical (there will be a wedge at an extremely small angle at the top of the weight) with a diameter of 2.75inches or 6.98cm.

An aluminum plate under the shoe is used as a ground. Aluminum was chosen because of its low density and therefore light weight and it is also easy to machine. This plate would be attached to the Kistler force dynamometer at the bottom of the plate and clamped at the sides in order to prevent it from moving. The length and width of the aluminum plate is 32cm and 15cm respectively. This is slightly greater than the width and the length of the shoe on which the insole would be placed. In order to determine thickness of the aluminum plate we carried out a stress analysis test.

In order to mark the high pressure areas of metatarsals and toe, cylindrical shaped carbon steel will be used. For toe a cylinder of diameter 2.54cm and height 1cm will be made. For 1st and 2nd and also 3rd, 4th, and 5th metatarsal areas, a cylinder of the same height but a diameter of 3.81cm will be used. The ends of these areas will be jagged so that there is more static friction between the high pressure areas and the insole. These high pressure areas will be welded to the connector or the steel plates.

Rigid connectors are used to connect the insole to the linear electric actuators. A small displacement is applied to the actuator which causes the connector, bolted to the actuator, to move. The high pressure area mentioned in the previous section will be welded to the connector if the shear forces are being measured for that region. For the other regions there will be a square carbon steel plate of 7.62cm by 7.62cm (the outer diameter of the steel tubes was 7.62cm) that will be supporting the tubes and weights.

The plywood support structure is there to align the steel welded vacuum tubes vertically when a deformation is applied.

The total cost for this project is $369.53

HEIGHT ADJUSTABLE TRANSFER SEAT

Designers: Cody Craine, Michael Harrison, Sarah Hopkins, and Nathan Smith
Supervising Professor: Dr. Albert Shih
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Ann Arbor, MI 48109

INTRODUCTION

For wheelchair users, it is difficult to transfer from the wheelchair to another seat. A sliding board is commonly used to make transfers, but its use requires extensive physical strength when the seats are at different heights. The goal of the project is to design a "Height Adjustable Transfer Seat" (HATS) to be used within a room containing exercise equipment which is able to adjust the height of the seat to allow level, and therefore easier, transfers to the NuStep T5. The HATS should be safe, easy to use, durable, time efficient, portable, comfortable, and have a good overall appearance.

SUMMARY OF IMPACT

We believe that the HATS prototype is a successful prototype. We believe that no full scale changes are required because the prototype functions properly and meets all of the engineering specifications. The HATS is able to accomplish its main goal of changing the height of a transfer chair to assist a customer in making level transfers when moving from a wheelchair to the T5 exercise machine. The height of the HATS is easily adjustable both upward and downward, so there is a lot of stress is taken off a caregiver during the transfer process. Additionally, the HATS operates at a safe speed so customers will feel comfortable while using the device. We are very supportive of the push-pull cable for lowering the device. This requires little strain on the caregiver and allows for the device to be stopped at any time during the decent. This eliminates the need to completely lower the HATS then re-actuate the jack to achieve a different height for the customer.

TECHNICAL DESCRIPTION

After performing parameter analysis of the HATS, we were able to create a design based on engineering conclusions. The HATS attempts to emulate current transfer seats in appearance. However, the HATS outdoes current transfer seat models in function. The design is centered on the ability of the HATS to change the height of its seat. The lifting component of the HATS is mounted to both the upper and lower frame. A hydraulic bottle jack is being used to lift the HATS, and a one way damper is being used to limit the decent speed of the HATS. To assist with the actuation of the bottle jack, the lever arm of the jack was replaced with a steel tube bent to form a foot pedal. To lower the HATS a push-pull control cable is attached to the jack orifice. When actuated this cable opens the jack orifice, thus allowing the jack to be lowered. The design consists of an upper and lower frame. The upper frame will resemble a typical chair, while the wheels and lifting components will be attached to the lower frame. The side supports of the lower frame will slide inside the side supports of the upper frame. The upper frame side supports has bushings press fit into them to allow for smooth and controlled sliding with the lower side supports.

There is a fifth wheel (swivel caster) located underneath the bottle jack to provide additional support to that section of the frame, which is subjected to significant loading. This wheel was chosen to be a caster so it will not inhibit the motion of the chair. The rigid casters in the rear will allow for straight line motion to be more easily achieved. To further assist with the transfer process the armrest of the original frame can be removed once the chair is at the proper height. This design was chosen because it will provide the customer with the necessary height change requirements, while also considering the safety needs of the customer.

Fig. 18.10. Height Adjustable Transfer Seat Prototype.

CHAPTER 19
UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

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Principal Investigator:

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ALPHABRAILLE

Designers: Seong-Hee Yoon, Lina Carballo, Quetrell Heyward
Client Coordinators: Diane Brauner, COMS
Supervising Professor: Richard Goldberg
Department of Biomedical Engineering
University of North Carolina at Chapel Hill
Chapel Hill, NC 27599

INTRODUCTION

Braille literacy enables people with visual impairments to read and write. Mastering Braille is especially challenging for children because memorizing the alphabet requires spatial perception, an acute sense of touch, and learning many dot combinations. While there are several fun and stimulating games that teach letters and phonics to children with vision, there are no comparable toys that teach Braille to children with visual impairments. Teachers usually have plastic sheets with Braille textures and practice reading them with their students. Although teachers are very helpful in engaging their students, these children do not have a fun, engaging way to work on Braille literacy outside of their school.

We developed a portable and washable electronic device that will help children with visual impairments to learn Braille and phonics. This device features the textures of the full Braille alphabet and a melodic description of each character. AlphaBraille provides audio and tactile feedback to provide a fun and engaging environment in which young students can learn. Parents and teachers can easily set the volume and replace the batteries.

STATEMENT OF IMPACT

We worked with Diane Brauner, an Orientation and Mobility Therapist, who provided feedback on our design from a clinical perspective. She commented that, "the kids can easily get [the puzzle pieces] in. The sounds are terrific. The tune is so catchy, and the kids are going to be singing it, which is great because they are going to be learning the dot numbers for the Braille letters. I think it's terrific. I think you guys did a phenomenal job. It's going to really help our kids learn Braille in a fun way."

TECHNICAL DESCRIPTION

Alphabraille consists of a base unit, and twenty-six semicircular puzzle pieces, each encoded with a letter written in Braille dots on the top face. To play with the device, the user selects a puzzle piece and pushes it into a matching cutout in the top of the Alphabraille base. This prompts AlphaBraille to play a song about that letter. The song includes the letter's name, phonics, dot numbers, a sample word, and a sound that represents the word. For example, Figure 19.1 shows the puzzle piece for the letter "B". When the user fits this piece in the matching black cutout on the base, the device plays a song to the tune of "Old Macdonald": B says "buh", bird starts with B, <chirp>, <chirp>, <chirp>. B says "buh", B says "buh", B is dots 1 and 2.

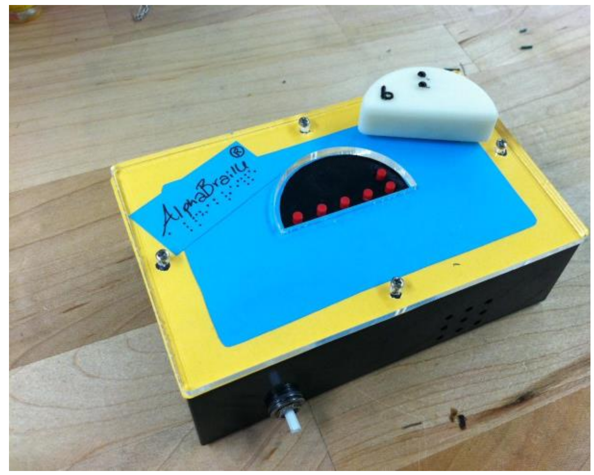

Fig. 19.1. The Alphabraille base unit and a puzzle piece for the letter "b". When the user fits this piece in the matching black cutout on the base, the device plays a song about the letter B.

Next, the user removes the puzzle piece and can insert another puzzle piece into the base. Kids can repeat this process multiple times to become familiar with the alphabet or to test their knowledge while having fun in the process.

The puzzle pieces were designed and fabricated using computer software and a 3-D printer. As mentioned above, each piece contains a Braille configuration on its top surface that represents a certain letter of the alphabet. The bottom of each piece contains a unique set of holes to identify the piece to the base unit. This is accomplished by activating a unique combination of the push-buttons inside the cutout of the base unit. For example, if the user inserts puzzle piece "G" then switches #1, 2, and 3 will be activated; meanwhile, if the user inserts puzzle piece "S" then switches #1, 2, and 5 will be activated.

A microcontroller detects the push-button combinations and plays the appropriate sound files. It controls the Rogue Robotics µMP3 Player, which stores and plays one of the twenty-six MP3 files corresponding to the letters of the alphabet. For instance, if the microcontroller receives signals from the puzzle piece "B," it sends an electronic message to the µMP3 Player to play the "B" song. The user can rotate a potentiometer to provide volume control. After the amplifier magnifies the output of the µMP3 Player, a mini-speaker transmits it to the user.

The total cost of this device is $360. This includes the cost of the plastic used in the 3-D printer to make the puzzle pieces.

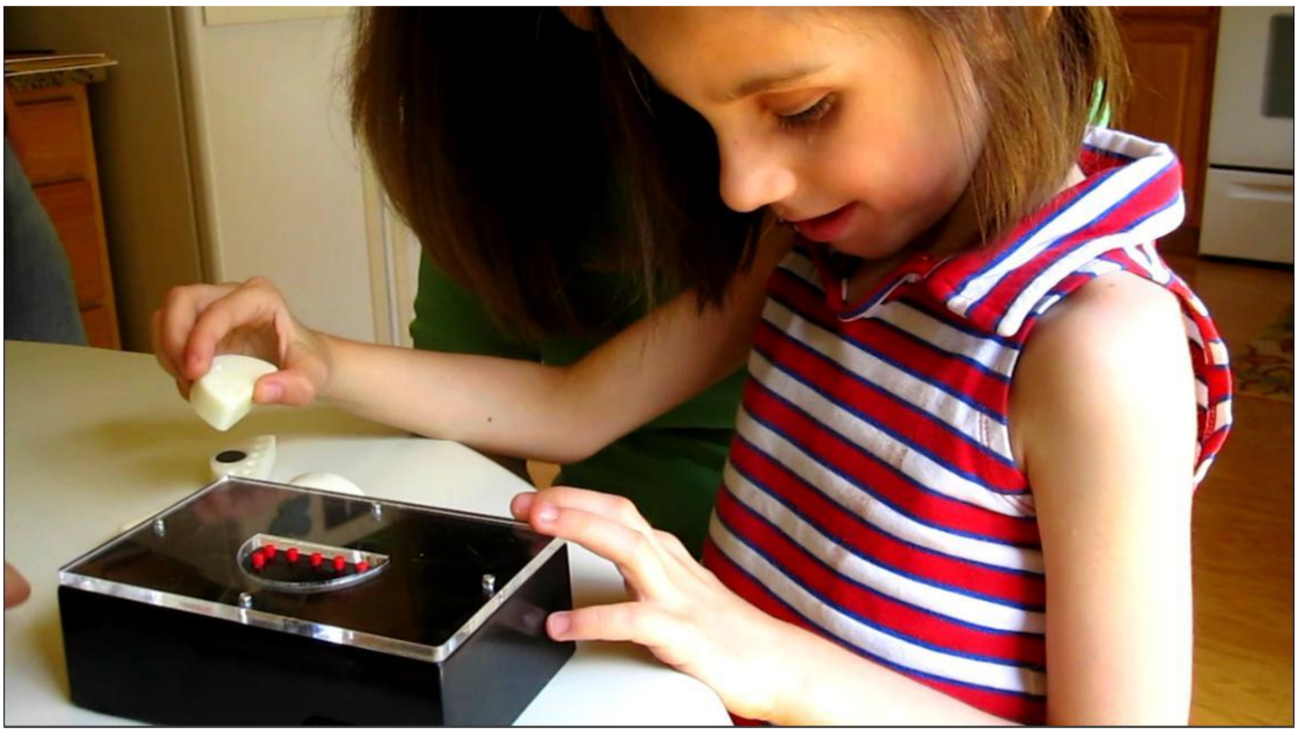

Fig. 19.2. Client using the Alphabraille device.

ONE LEG UP

Designers: Matthew Davis, Rebecca Mann, Kenneth Addison
Client Coordinators: Katie Stephens, PT
Supervising Professor: Richard Goldberg
Department of Biomedical Engineering
University of North Carolina at Chapel Hill
Chapel Hill, NC 27599

INTRODUCTION

Our client, Joyce, is a middle-aged woman with Multiple Sclerosis, which is a chronic disease that attacks the central nervous system and results in decreased muscle strength. Joyce has significant weakness in her legs, such that she cannot move either leg independently while seated or supine because she cannot overcome the friction force between her leg and the resting surface. To address this issue, her physical therapist has been working with Joyce to increase leg strength. At the clinic, Joyce lays supine on the table, and the therapist lifts her leg above the table by attaching straps around Joyce's thigh and ankle, and connecting the other end of the straps to a hook in the ceiling. With Joyce's leg suspended above the table, she can freely move it from side to side to develop better strength. She repeats these exercises with both legs. Since she began these exercises, she has already noticed an increase in her lower body strength, and she wants to be able to do these exercises at home on a daily basis. Therefore, Joyce needs a means to raise her legs over the surface of her bed, one at a time. However, she needs to be able to do this independently, as she lives alone, and she cannot attach anything to the ceiling, as there is a ceiling fan above her bed.

We developed a device that attaches to Joyce's bed and lifts her leg over the surface so that she can conduct a variety of leg exercises independently. With her leg suspended above the bed, she can lie supine and swing a leg from side to side. She can also lie on her side and perform an exercise that targets her hamstrings and quadriceps. The device has connection points for additional straps, which will enable her to conduct more strenuous exercises in the future.

SUMMARY OF IMPACT

After the first test run with a prototype, Joyce said "I am excited about having this [device] because it will allow me to move my legs, to exercise them, and make them stronger, and that's what the goal is right now." On the day of the final delivery, the physical therapist said, "you guys put together a great device and I think it will be very useful for Joyce to practice her home exercise program independently. She may need a little help at first but eventually it should be a great tool for her to continue to get stronger."

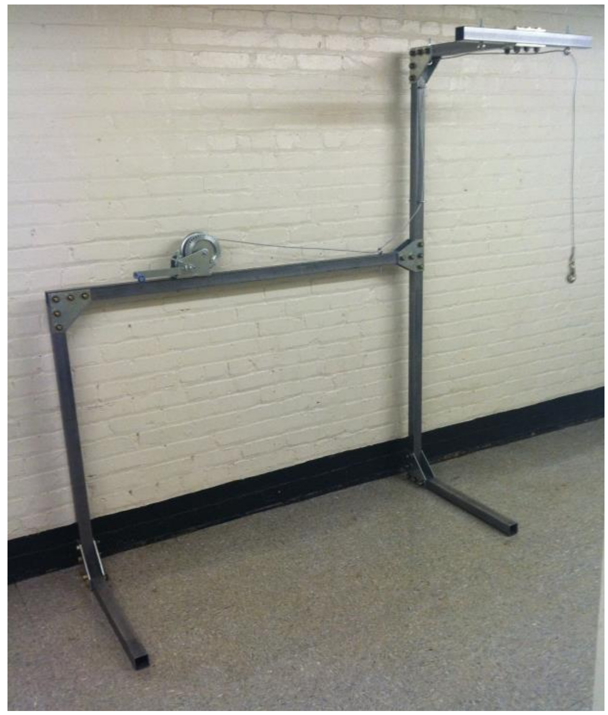

Fig. 19.3 Photo of the One Leg Up Device before it was powder coated in white and attached to her bed. The left side of the frame is toward the head of the bed, where the client can reach the winch, and the clients legs are attached to the part of the frame that cantilevers over the bed. The legs at the bottom of the frame will attach to the bed.

TECHNICAL DESCRIPTION

Our device consists of a steel frame that attaches to the base of the client's bed. This acts as a support system for two ropes that hang over the center of the bed. The client places a Velcro strap around her thigh and another strap around her ankle and connects the straps to the overhanging ropes using carabineers. Once connected, she uses a winch to crank her leg up to a comfortable height, typically 6-12 inches above the bed. After she completes each exercise, she can reverse the direction of the winch and lower her leg in a steady and controlled manner. She can repeat this process on the other leg.

The frame of the device is made from of 2″x2″ rectangular steel tubing. The base of the frame slides into matching 2″x2″ slits that are cut into the wood blocks fit under the legs of her bed. This was done to allow the weight of the bed to counteract the torque created by the movement of her leg. Because the frame was only slid under the posts of one side of the bed, we also added blocks of the same height to the other side of the bed to make it level, while still at an appropriate height for the client to transfer from her wheelchair. The frame of our device supports the winch and the rope. It runs along the side of the bed and cantilevers over the middle of the bed so that the client's leg can be raised above the bed.

The hand winch was selected to allow the client to have manual control when raising and lowering her leg. To accomplish this, a 1,000 pound capacity Haul-Master® winch with bi-directional control was selected. The client is able to raise her leg by turning the handle, and then press a simple switch to reverse the ratchet direction. Then, she can rotate the handle in the opposite direction in order to lower her leg one gear tooth at a time. This feature is necessary to ensure that the client would be able to control the speed at which her leg was lowered.

The winch is wound with 30′ of dock line rope, rated at 240 pounds. The rope is guided along the tube using eyelets. After the rope reaches the cantilever, it is tied off into a loop and a second piece of rope is run through this loop, with carabineers attached to each end. This design allows the client to connect the rope to both her thigh and ankle at the same time. The crank could then be turned to raise her leg or lower it, giving her full leg placement control.

The total cost of this device is $400.

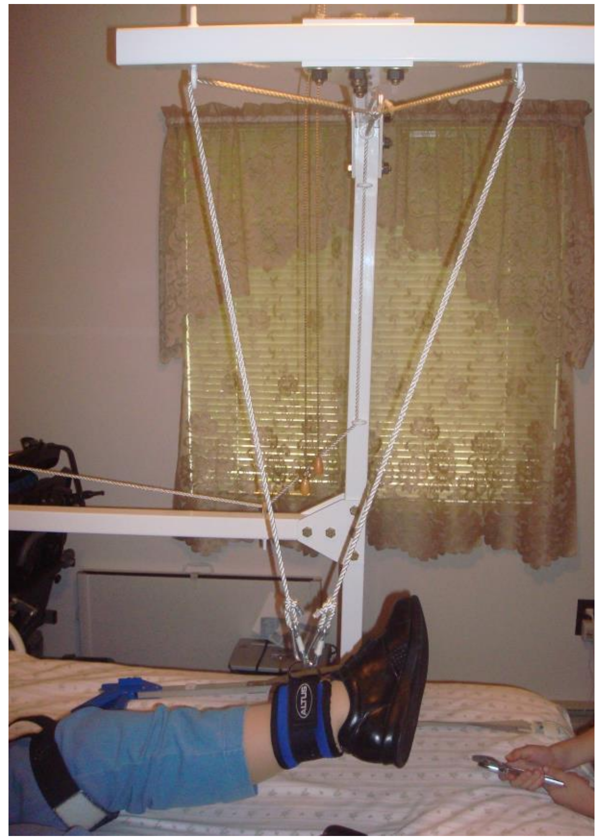

Fig. 19.4. Client using the device to perform her leg exercises.

THE FINAL STRETCH

Designers: Jeff Sechrist, Shrey Patel, and Brad Hubbard
Client Coordinators: Keith Jacobsen, PT
Supervising Professor: Richard Goldberg
Department of Biomedical Engineering
University of North Carolina at Chapel Hill
Chapel Hill, NC 27599

INTRODUCTION

The North Carolina Jaycee Burn Center at the UNC-Chapel Hill hospital provides burn care to both inpatients and outpatients. Depending on the location of the burn, a patient may experience decreased range of motion in their limbs due to the non-elastic nature of the newly grafted or burned skin. As a result, the patient must stretch the affected limbs at least 2 times a day, for up to an hour each time. This will stretch the damaged skin and recruit new areas of nearby healthy skin to facilitate this stretch, which helps to maintain and extend their range of motion. This time consuming exercise is currently being done in the clinic by a physical therapist (PT). However, this is not an efficient use of the PT's time. In addition, when the patient is ready to return home, they no longer have daily access to the PT for these stretches and as a result, their range of motion may regress.

We developed a shoulder and arm stretching device that the patient can use independently, both in the clinic and at home. The device facilitates a particular stretch that the PT performs: a straight flexion of the arm, with the patient in a supine position and the arm moving back toward the head. The goal is to achieve full range of motion, which is a 180 degree angle between the torso and arm. Our device provides feedback of the current arm angle so that the patient can maintain and increase the range of motion. The device is easy and comfortable to use, which is important because patients can be sore from their burn.

SUMMARY OF IMPACT

The device has been tested with different patients, both to increase and to maintain range of motion. One patient had prominent scar bands around her shoulder that needed to be stretched and the device was efficient in opposing the constricting force of her skin. Another patient already had full range of motion but needed to continue stretching exercises to maintain that range. After initial testing, Keith Jacobson, PT, commented that the "device allows the shoulder to undergo stretching in manner more comfortable for both the therapist and the patient". Ralph Stoehr, PT, said that "is it nice that the patient can use it independently while having the ability to go up to a 180 degree stretch angle." This frees the PTs to do other activities. Keith added that "the design of the device allows it to be easily portable and used on both shoulders". The stretching device is also beneficial in the home setting.

Fig. 19.5. The Final Stretch device. In this view, the head would rest on the left and the torso to the right, and the winch lever arm is positioned for left handed operation to crank the right arm back.

TECHNICAL DESCRIPTION

The device is used either on the floor or on a bed and the patient lays in the device in a supine position, their legs extending off of one end. Their affected arm rests in a cuff at the end of a rotating rod, with a center of axis of rotation that is next to the shoulder joint. At the start of the stretch, the arm is pointing vertically toward the ceiling. Then, the patient cranks a winch mechanism, which pulls on a cable that then pulls on the rotating rod to slowly pull their arm back. The winch will hold the position for an extended period of time, until the patient, clinician, or their caregiver is ready to release it.

The base of the device is a 2x3 ft plywood board with foam cushioning and vinyl upholstery for comfort and easy cleaning. The winch (Haul-Master) is attached to the board with acrylic groove mounts. The user operates the winch by alternately pulling and pushing a lever using their healthy arm. For the cable, we used a stranded metal cable with plastic sheathing. The cable enters the pulley system that is mounted on the base, which translates the cable around the user's head to the affected side. In this manner, the patient can use their healthy arm to increase the range of motion of their affected side. The winch has a release mechanism that releases tension on the cable so that the user can move their arm back into a resting position next to their torso.

The rotating rod was attached to a hinge on the board that allows it to swivel freely in the desired direction. The arm can be secured to the far end of the rod in a variety of ways, depending on the patient's injury. One option that we designed is hard-shell arm cuff made from a padded half-pipe of PVC hinged to another half-pipe. The two half-pipes are brought together to form a 4" diameter cylinder that surrounds the patient's elbow. This ensures that the elbow will not bend during the stretching. Before mounting the arm in this cuff, the patient or clinician can wrap bandages around the arm to protect any burned skin in that region.

An electronic angle reader is mounted magnetically to the rotating rod to give so that the patient and their clinician can monitor the current stretching angle and build toward increased range of motion.

The device is easy to set-up for the patient and it is also portable, adjustable, and innovative. In a few minutes, the device can be easily reconfigured to stretch either the right or left side. The total cost of this project is $185.

Fig. 19.6. A patient using the Final Stretch device.

ASSISTIVE TECHNOLOGY FOR THE IMPROVEMENT OF HEAT SHRINK WRAPPING

Designers: Sarah Jastram and Parth Tarasaria
Client Coordinator: Tracey Craven and Amanda Crawford, OE Enterprises
Supervising Professor: Richard Goldberg
Department of Biomedical Engineering
University of North Carolina at Chapel Hill
Chapel Hill, NC 27599

INTRODUCTION

OE Enterprises trains people with learning disabilities and limited dexterity to do contract work at their facility. One of the jobs involves collating and packaging paper brochures using a commercial heat shrinking machine, which is in need of adaptations for safer use by operators who are seated in a wheelchair and/or have limited dexterity. The heat shrink machine is operated as follows: the user gets a stack of documents to be wrapped and places them on the loading station between two layers of plastic. Still wrapped in plastic, the user pulls the documents by hand to the pressing station. Once in the correct position, the user grabs an L-bar arm containing a hot wire and lowers it onto the plastic sheathed document. This cuts and seals the plastic around the documents. The arm is then lifted back up and the document is moved to the heat shrink tunnel.

The machine is designed to be used from a standing position, and many employees at this facility cannot stand for extended periods because of their disability. In addition, some of the steps are difficult for employees with poor motor control. Finally, the machine uses a hot wire to cut the plastic material, which presents a safety hazard. To address these issues, we modified the heat shrink machine in order to make it accessible, safe, and easy to use for users with limited dexterity and users in wheelchairs. The individual goals were to: improve the ease of sliding the documents from the loading station to the pressing station in a neat fashion; extend the L-bar arm so that it is easy to reach from a seated position; and protect the user from burning hazards.

SUMMARY OF IMPACT

We observed several OE clients use the modified heat shrink machine and they said that the modifications made it much easier to use the heat shrink machine. OE Program Services Manager Amanda Crawford remarked that "Before [the machine] was not very accessible to people in wheelchairs or that have mobility issues or have difficulty with upper body strength. Now it is easier to pull down, pull the plastic wrap across the machine, and makes it easier overall for some of our individuals to use it."

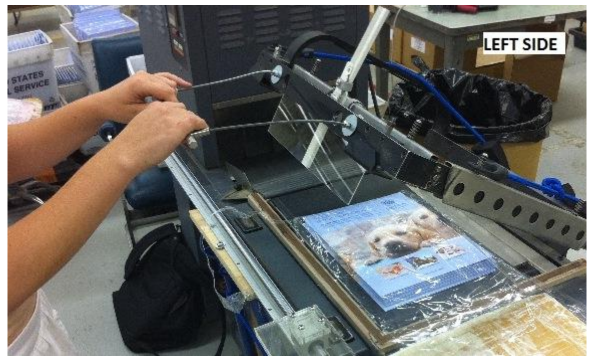

Fig. 19.7. Two views of the adaptations to heat shrink machine.

TECHNICAL DESCRIPTION

The modifications made to the machine were split into several parts: a push slider that pushed the documents from the loading to pressing station; a roll holder that facilitated the distribution of the heat shrink plastic; an arm extension that enables the user to easily lower the L-bar arm from a seated position; and a retractable shield that shields the hot wire from the user, while the L-bar arm is in the up position.

The push slider enables the user to easily move the plastic sheathed documents from the loading to the pressing station on the heat shrink machine. It also keeps any hands and fingers away from the dangerous hot wire. The slider is in the shape of a backwards "L". The long arm of the L acts as a pusher that pushes the documents, and the perpendicular arm serves as a handle for the user and a connection to a linear sliding track. The pusher sits behind the document by default; the user grabs onto the handle and pushes against the document towards the pressing station. After sliding the document to the pressing station, the user then slides the pusher back to its default position.

The push slider was made from L-shaped acrylic plates bolted together to give it the thickness it needed to push the documents. The front edge of the plates have a slit that provides a handle for the user. The pushing edge of the plates have rubber along the bottom in order to provide better contact with the documents that they are pushing. The slider is attached to a linear rail to provide smooth, repeatable movement of the documents for individuals with poor motor control.

The heat shrink plastic comes in large, heavy rolls. In order to facilitate the pulling of the plastic from the roll, we designed a holder that utilizes an 18" conveyor belt roller. This roller contains steel ball bearings for smooth rotation even under a heavy load. The roller's axle rests on two panels of wood placed on either end. These two side panels are reinforced with a bottom panel that holds the vertical panels upright and prevents the holder from tipping over when lateral force is applied. The wooden holder was clamped to a table that sits adjacent to the heat shrink machine.

In order to facilitate operation of the L-bar cutting arm from a seated position, we designed an extended handle that attaches onto the cutting arm. We also mounted a gravity-operated retractable shield that blocks user from touching the hot wire when the arm is up and retracts when the arm is pressed down. The arm is made of acrylic. The weight of this mechanism prevented the L-bar arm from automatically springing to the up position when not in use. Therefore, we attached bungee cords to the backside of the L-bar arm. This allowed the arm to retract automatically to the up position.

The total cost of these adaptations is $300.

Fig. 19.8. Client using the heat shrink machine.

CHAPTER 20
UNIVERSITY OF SOUTH FLORIDA

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OMNI-DIRECTIONAL WHEELCHAIR BASE

Designers: Jonathan Alzate, Alan Gutierrez, Felipe Hurtado, Diego Palacio
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INTRODUCTION

People in wheelchairs only have the capability of moving back and forth due to the limited range of motion of the chair. Our project solves this problem by giving the user the ability of moving in ten different directions. We decided to go with a car like base design with four wheels and four motors, one at each wheel. The wheels have 12 rollers at a 45 degree angle that, when used correctly, will give the direction desired. The existing problem with our design is that each motor is very heavy and powerful, which makes the base heavier than what we wanted. Less powerful but lighter weight motors would be an improvement to the design.

SUMMARY OF IMPACT

We believe that this product will improve the life of people with disabilities because they will feel more comfortable and more secure with their movements. For example, they will be able to do chores around the house better because they are not restricted by limited mobility. They will be able to maneuver around furniture with ease.

TECHNICAL DESCRIPTION

Our design is based on the use of the Mecanum wheel, which will allow us to achieve the desired directions by placing the wheels in the correct sides and angles. The DC motors that we used are from actual electric wheels chairs. They are rebuilt motors and we chose them because they come with the gearbox attached, making the assembly easier. They are rated 24V DC and 3.3 Amps but they can also be changed to meet any desired specifications. The circuit that will drive the motors and therefore the wheels is composed of a Field Programmable Gate Array (FPGA) which is used to take digitals signals from the control panel to generate the Pulse Width Modulation (PWM) signal and process the direction signal. The FPGA is programmed with Very High Speed Hardware Description Language (VHDL), this tells the motor to move clockwise or counter clockwise depending on where the user wants to go.

Fig. 20.1. Omni- Directional Wheelchair with Mecanum Wheels.

The Pulse Width Modulation (PWM) controls the amount of voltage (0-100%) that will be sent to the motors at any operating time, therefore giving the user the desired speed. The design consists of ten different speeds, which range from 0-9, where the zero voltage is the stopped position or no voltage is sent to the motors. The direction and PWM signals are then sent to the motor drivers at 5V where they are converted to a 24V signal and sent to each motor with its own direction, depending on the targeted movement of the whole chair. For the different directions, switches are used and for the accelerator a knob with each speed numbered from 0-9 is used. These can be implemented to a joystick if desired. We used scrape materials to make the base, and a used chair donated by the professor. The most important parts of our design are the Mecanum wheel, the circuits, and the motors. The total cost of our project was $1,135.60.

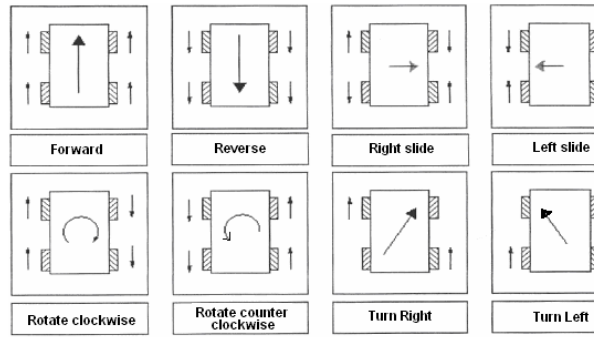

Fig. 20.3. The possible directions the wheelchair can move.

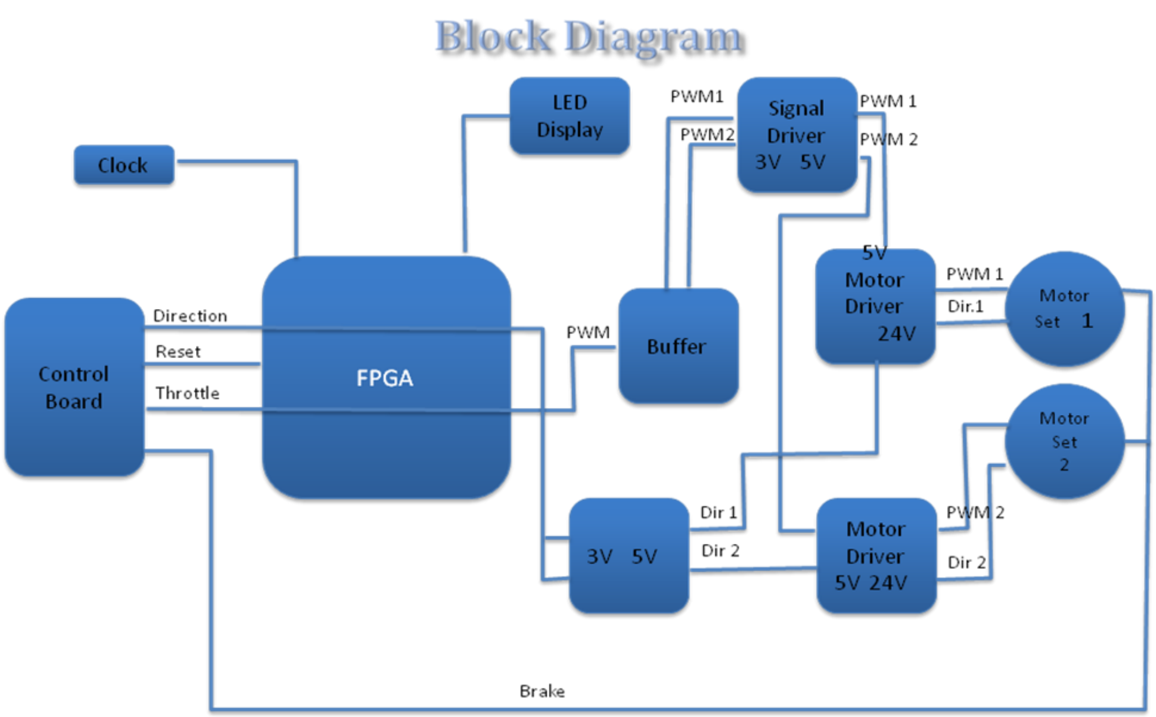

Fig. 20.2. Block diagram of the circuit.

OMNI-SPHERE WHEELCHAIR BASE

Designers: Jamison Fiebrandt, Greg Kavan, Kenza Mouttaki, Janet Gregalot
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
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INTRODUCTION

For the purpose of this design class, we designed a wheelchair base which allows the user to move side to side instead of going through the traditional backing up and pulling back in. Our wheelchair base also has the motion of the common powered wheel chair; forward, backward, turning left and right.

SUMMARY OF IMPACT

Our primary objective was to build and design a prototype of a base that will allow motion to users left and right without reducing the motion of a common power wheelchair. The base had to also have a soft touch on the floor which will avoid scuff marks or tear on carpets or hardwood, be able to overcome a two to four inch curb or ledge, ramps with a grade of 12° or less, and similar obstacles and finally, had to be able to reach a maximum speed of 7 mph with a load of 350 lbs.

TECHNICAL DESCRIPTION

The design that was used for our prototype consists of two spheres friction driven by wheels with rollers on them allowing the sphere to rotate in a direction normal to the wheel. The basketball's 9.5 inches diameter allowed the base to overcome ledges up to 4.75 inches high which exceeds our two to four inch design parameter. The eight roller wheels are driven by 6 motors. Every sphere is controlled by 3 motors which control the three conventional directions; forward, backward, side-to-side. Every roller is placed at 90 degrees from the other, with 4 roller wheels on each sphere. The selection of the parts was made for a proof of concept only. The motors chosen allow the prototype to run at 2 mph as opposed to the calculated 7mph. The choice of basketball as opposed to custom made rubber sphere also contributes in limiting the speed of the base if weight is added to it; this is due to the friction of the floor with the basketball and the speed of motor.

We did achieve omni-directional motion allowing the wheelchair user to move side to side without.

Fig. 20.4. Photograph of the Omni-Sphere Wheelchair Base.

This convenience was our primary design objective. The design is able to go up a twelve degree ramp, overcome two to four inch ledges, and can be used in moderate terrains or environments. The only design objective that we did not meet was the speed of the wheelchair. Overall, our design is effective for use with a base of an omni-directional wheelchair.

The final price of all of the materials for the prototype was about $600. The largest portion of this cost was for the motors and controllers with a cost of $173.96, followed by the wheels, the brackets, the controls – Arduino Uno Board and 3axis joystick- and finally the metal framing which cost $35.

As recommendations for future improvements, the use of higher speed motors will allow the base to move at a speed proportional to a person walking.

Also, to prevent the base from being stuck in a pot hole, four spheres could be used instead of two; this would prevent the chair from being dependent upon only one sphere if the other is stuck. Finally, custom-made spheres with a lower coefficient of friction can be used.

Finally, we would like to acknowledge the USF SAE shop who permitted us to use their tools and spaces to perform the required machining and whose members helped with the welding.

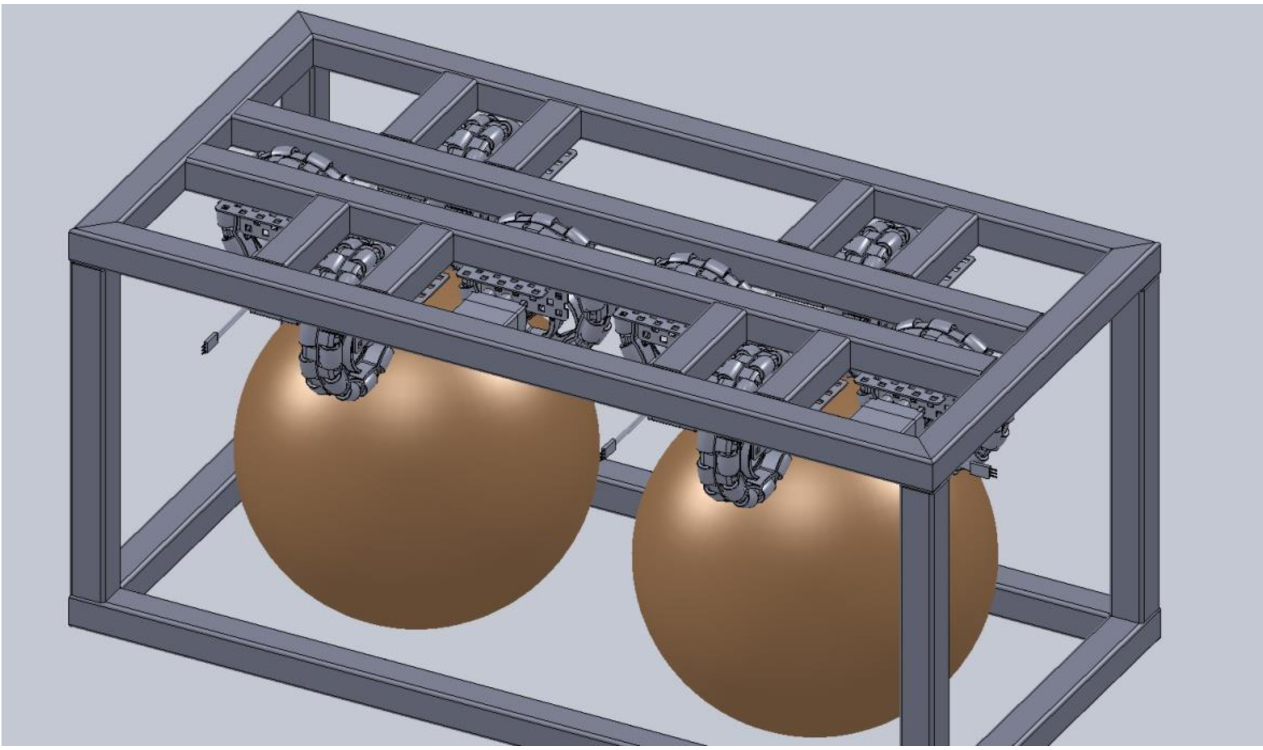

Fig. 20.5. Computer Rendering of the Omni-Sphere Wheelchair Base.

OMNI-DIRECTIONAL POWER CHAIR

Designers: Carlos Wilfong, Brady Cole
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
Department of Mechanical Engineering
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Tampa, Florida 33620-5350

INTRODUCTION

Power wheel chairs are increasingly prevalent in today's society. With constant empowerment for those with disabilities and a steady stream of battlefield wounded soldiers desiring more fulfilling and versatile lifestyles, the demand for power chairs with greater mobility and agility is growing. As it stands now, the most agile chairs with the tightest turning radiuses are the "center-wheel-drive" models that can effectively spin on a zero degree axis. Even this level of maneuverability can require a lengthy forward and reverse cycle of movements to simply "scoot over" at a dinner table.

Also the side to side movements that are common with cooking in a residential kitchen, even with abundant floor space, are prohibitively constrained by standard power chair construction today. With these considerations in mind it can be realized that there is a market for a new, more maneuverable design power chair. This report explores one such design and if it is successful, could assist in eliminating more boundaries and limitations, both physical and mental, currently being faced by the disabled.

Summary of Impact:

The development of an Omni Directional power chair drive system that can strafe from side to side would be most beneficial to the user who has been recently begun to use a power chair and is, for the most part, unfamiliar with the mobility limitations therein. A final version of this product could be marketed to the Veterans Administration for use with wounded soldiers. The greater mobility and agility associated with this design might positively impact the lifestyle of the user by lessening the psychological recovery time from any event that could place one in a power chair.

Technical Description:

Most of the time power chair usage is standard distance movement that requires no special drive

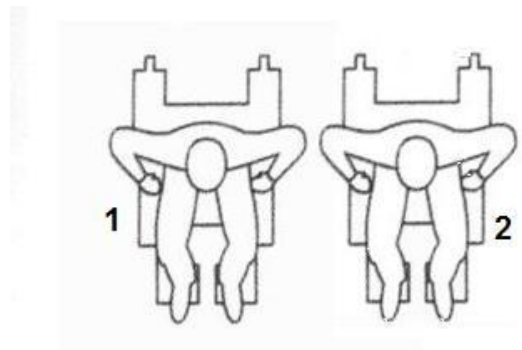

Fig. 20.6. Conventional Power Chair Maneuverability.

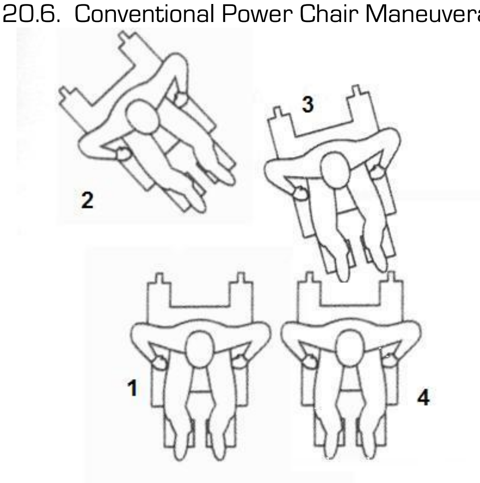

Fig. 20.7. Proposed Power Maneuverability.

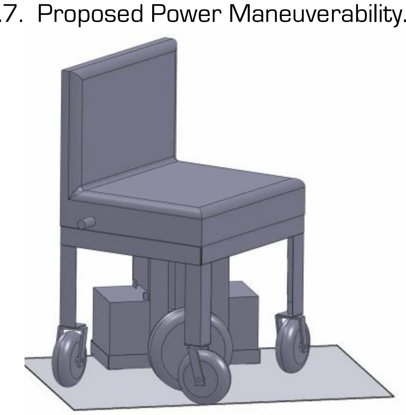

Fig. 20.8. Model View.

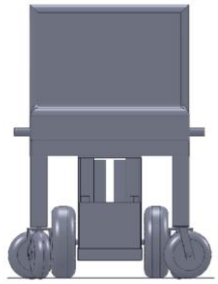

Fig. 20.9. Forward (standard) Motion.

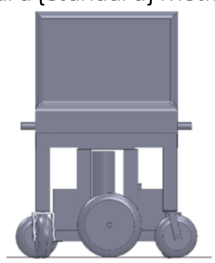

Fig. 20.10. Strafe (side to side motion).

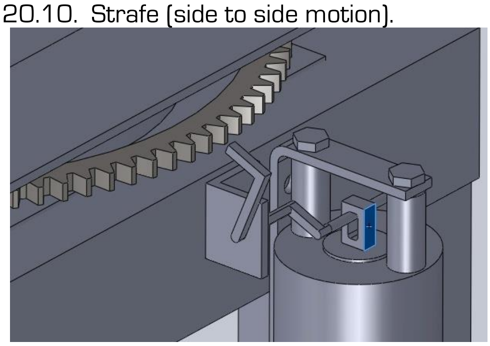

Fig. 20.11. Unlocked (energized).

systems out of the ordinary. This system places all major components into a housing that can spin beneath the operator independently of the operator himself.

This component cluster is called the "Drive Column". Under normal operation, the drive column is locked in position so that the wheels operate in much the same way as a normal "center-drive" system, albeit with an even tighter turning radius. When strafing motions are required, a control is used that activates a solenoid that unlocks the column from the rest of the chair.

Then the column can be made to spin independently beneath the operator with just actuation of the drive wheels. When the desired position of the drive column is reached the locking mechanism reengages (rest position) and travel can begin again.

The total cost for this project utilizing "free" labor from the University's machine shop is $ 626.47. Some

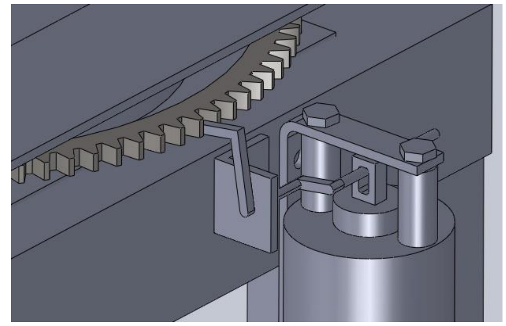

Fig. 20.12. Locked (rest).

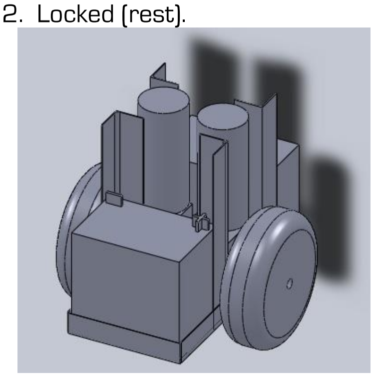

Fig. 20.13. Drive Column .

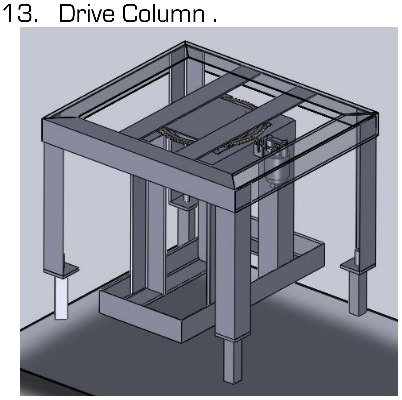

Fig. 20.14. Overall Construction.

parts for this prototype were donated thus have a 0.00 dollar value. Also the bulk of the parts, including hardware, were obtained by buying a complete Jazzy Mobility scooter from EBay, thus keeping costs down.

K-POD: A CHILD MOBILITY DEVICE

Team Pleonasm: Christopher Dotson, Jakob McClelland, Qi Ni, Kathleen Simpson
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
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Tampa, Florida 33620-5350

INTRODUCTION:

This device is designed to assist children with mobility difficulties between the ages of 1 to 3. It can be controlled either by an external controller or the attached control panel. Comparing to similar devices on the market, it is portable and light weight.

SUMMARY OF IMPACT:

Most people develop their learning abilities between the ages of 1 to 3. Being able to look around and touch everything are the most essential parts of learning. The biggest difficulty for children with physical disabilities, with respect to learning, is the lack of self-mobilization. Studies have been performed that show that a child's mind grows exponentially once they learn how to crawl and walk for themselves. The most common way for a child with disabilities at a young age to get around is by being carried. This mobility device will help the user to move around independently.

Fig. 20.15. The Finished Child-Mobility Device.

Technical Description:

As shown in Figure 20.16, the device is powered by a single 6 volt battery. Two independent geared motor power the side wheels. The seat top is removable which also reduces the weight when carrying the device.

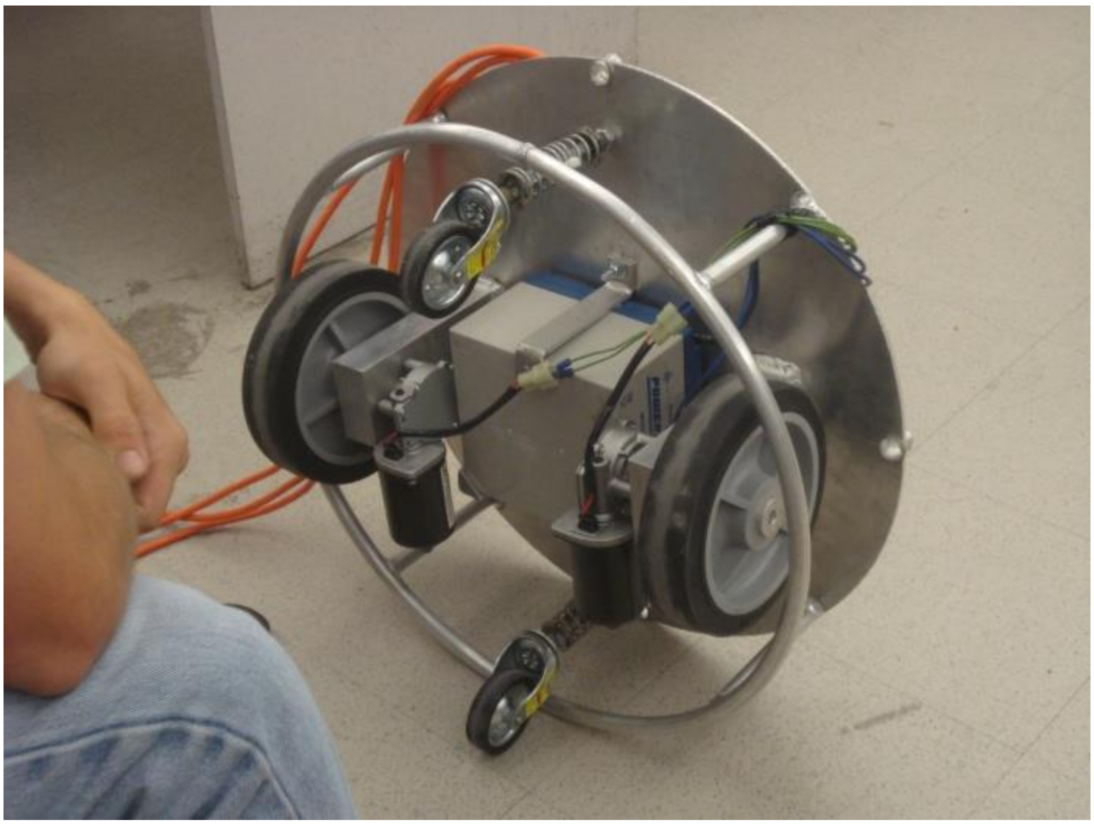

Fig. 20.16. Base of K-Pod.

CHILD MOBILITY DEVICE

Crawling Turtle Labs: Joey Sacco, Glen Currey, Laura Carpp, Daniel Wilkinson, William Foote
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
Department of Mechanical Engineering
University of South Florida
Tampa, Florida 33620-5350

INTRODUCTION

Today's society expects a lot from any one person. Motor skills can make or break a person, especially that of a developing toddler. Children diagnosed early with paraplegia have an extremely difficult time developing the motor skills of their upper body due to the lack of the function below the waist. For this reason, a system needs to be developed to assist in developing these motor skills early.

SUMMARY OF IMPACT

The Crawler 1 is a mobility device for handicapped children ages 1-3 years. The premise behind the design is to enable children, who are disabled, the opportunity to be mobile; experiencing and interacting with their surroundings just as a normal child would. The Crawler 1 can accommodate a variety of disabilities due to its seating and restraint design. The design features simple controls for easy maneuvering and an 18V cordless drill type battery pack for versatility and easy recharging. The Crawler 1 has an operator capacity of 50lbs and top speed of 4 mph.

TECHNICAL DESCRIPTION

We decided to design the prototype frame from mainly steel, due to the lower cost, ease of fabrication of cutting and welding, and because it is readily available locally. If the device were to be mass produced, an ideal replacement material would be injection molded plastic to reduce cost, weight, and manufacturing time.

Our drive system is comprised of two wheels located in the rear of the vehicle, each with one motor attached directly, with a planetary gear reduction in line to increase torque of the vehicle. This design also slows the overall speed of the vehicle to something manageable by a child of three years or younger. The motors and planetary gears were removed from a 14v cordless drill to simplify the design and keep the prototype affordable. The front of the vehicle is supported by two casters which allow the device to pivot left and right when the rear wheels are powered.

The controls for the prototype were kept simple to illustrate the principle method of control for the vehicle. Two momentary DPDT style toggle switches are used to control the motors. Each switch (one on each side of the seat) is located strategically where the child's hands would naturally sit when in a seating position. When the switch is pushed forward, the wheel will move forward accordingly, and when it is pulled back, the wheel associated with the switch will roll backward.

The seating was chosen to fully support the child using the device, and safety restraints are used to keep the child in the seat in the case of a misbalance during use. This will also provide the child with a sense of security during operation. A leg support is attached to the main seat also, in order to provide the child with a support of their legs while in motion.

To power the prototype, simple NiMH rechargeable batteries were derived from the same cordless drills used in the drivetrain. This kept the cost very low, and allowed for easy recharging of the batteries. The charging station from one drill was used as a mounting socket on the device, while the second is used for charging the battery when not in use. Since one battery is being charged while the second is being used, it provides more runtime of the vehicle overall. The NiMH batteries are perfect for this use, since they do not hold a memory from the lack of a complete discharge, so their life will be much more reliable for a vehicle of this type.

Fig. 20.17. Finished Child Mobility Device.

BEAD LAUNCHER

Designers: Team BBB: Ryan Lybbert, Ronald Fleurantin, Younes Benkabbou
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
Department of Mechanical Engineering
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Tampa, Florida 33620-5350

INTRODUCTION

Our project consisted of building a mechanical device that can project Beads into a crowd while being mounted in a way that a person with prosthetic limbs can operate with ease. We decided to build a mechanism that uses compressed CO2 to release bursts of gas to propel the beads to the crowd. This mechanism will be attached to a belt in a way that is easy to rotate and operate.

Some mechanisms that we examined for this application were for examples: a catapult, a sling shot mechanism, compressed air, and a compressed spring system. However, the problem with all of these mechanisms is the weight and power sources. The catapult is not practical to be portable, and the sling shot and spring systems both need a sufficient power source to load and reload the working mechanisms and do not fit this application. Compressed air is a good idea; however, air containers can be heavy and large air tanks would be needed to provide for more possible uses per tank fill.

SUMMARY OF IMPACT

After meeting with Joe, his excitement was very obvious and was our main motivation throughout the project. Joe is a person with two prosthetic limbs that participates in the Gasparella Parade as a Rough Rider member. With the help of the Bead Launcher he is now able to toss many beads into the crowd with ease! This project will give Joe an advantage on everyone else since he can launch beads way farther and with just a push of a button.

Fig. 20.18. Final Product – the Bead Launcher.

TECHNICAL DESCRIPTION

The Bead Launcher is composed of a 3000 psi 48 cu in. CO2 tank that is attached to an air regulator to control the pressure leaving the tank. This pressurized gas coming from the regulator is directed to a three way solenoid that is connected to an air cylinder. A plate is connected to the end of the air cylinder where the beads are placed. Three nine volts batteries power the solenoid and a push button activates it. A SPST toggle switch is also used to cut off the power for safety reasons (Figure 20.19). The entire mechanism is mounted on a friction hinge that allows rotation in order to give the user better aim and control.

Our cost for the entire project was $698.45 although some improvements can easily be made to significantly reduce cost. Different vendors can and will significantly reduce the cost. Due to inexperience and other factors such as machine shop discrepancies we were unable to keep our targeted weight goal of ten pounds. However, some improvements would be to use a smaller and more efficient air cylinder as well as building the main housing out of a composite material such as carbon fiber. The design works and functions like it was intended. With the apparatus hanging from a belt, the mass of the cannon becomes even more important because it creates bending moments on the material that joins the cannon to the belt. A sturdy lightweight material will be required and proper balancing of the cannon in relation to the friction hinge will alleviate these unwanted bending moments.

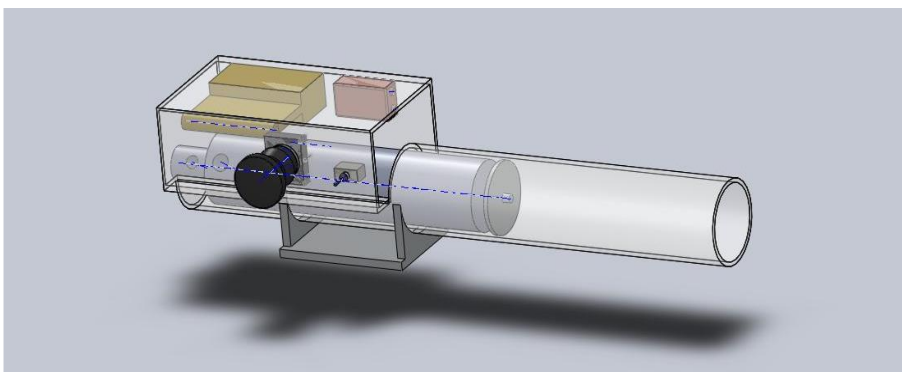

Fig. 20.19. Solid Works Model.

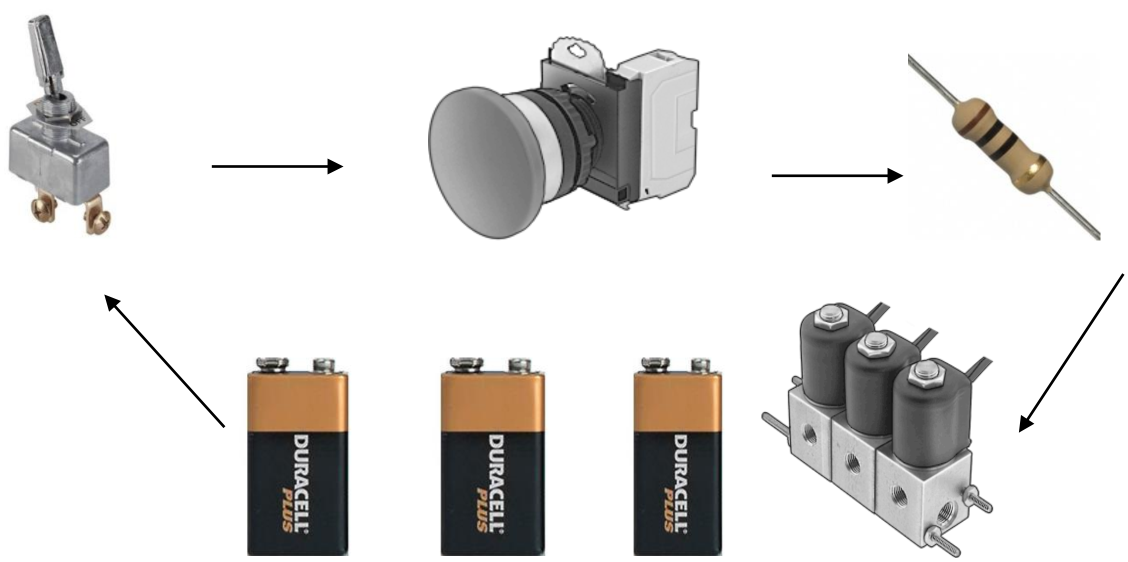

Fig. 20.20. Electrical System.

BEAD LAUNCHER: THE BLUNDERBEAD

Designers: Philip Logan, Joseph Houghton, Michael Maroney, George Wilson
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
Department of Mechanical Engineering
University of South Florida
Tampa, Florida 33620-5350

INTRODUCTION

PJMG Engineering is tasked with designing and developing a mechanical device to launch beads into a crowd of crazed pirate lovers partaking in the Gasparilla Parade in Tampa Florida. The device is designed for our customer who was born with no arms but has two prosthetic arms each with a hook mechanism at the ends which operate as his hands. Our customer is capable of using only the left arm and hook within a limited range of motion. The device must launch standard sized parade beads, safely, into a crowd roughly 30 to 40 feet away over a fence roughly 6 feet tall. In order to design the projectile device the customer was met and his capabilities were discovered. The customer's particular range of motion was established as well as the customer's ability to manipulate objects and switches using his hook. It became immediately apparent after the initial meeting that the design should resemble a Blunderbuss weapon of old; the barrel being large enough to simply drop beads into using only a hooked prosthetic arm. The device is to be mounted to the customer's hip via locking clips and slung over his opposite shoulder to bear the weight which will also angle the device near a 45 degree angle allowing for the maximum distance and most safe launch of the beads. After loading the beads from the top using the left arm and hook the customer will pull a trigger located underneath the stock which will activate the device and launch the beads. A safety level switch located inside the weapon will disallow any firing if the device isn't properly angled at or above 45 degrees.

SUMMARY OF IMPACT

Our customer will be participating in the Gasparilla parade for the first time as a newly anointed Rough Rider. The 1st U.S. Volunteer Cavalry Regiment "Rough Riders," Inc. was formed for the purpose of creating and perpetuating a living memorial to the unique accomplishment of President Theodore Roosevelt and the members of the 1st U.S. Volunteer Cavalry Regiment known as the "Rough Riders". It is only appropriate that our customer is able to participate in the parade by throwing beads into the crowd by his own accord. The Blunderbead will allow our customer to walk the entirety of the parade either on his own or on the float completely independent of others for help. It will be loaded by our customer, aimed and fired by simple straightforward movements gathered from our customer's trial run. Giving our customer the chance to actively participate in this event put a very big smile on his face.

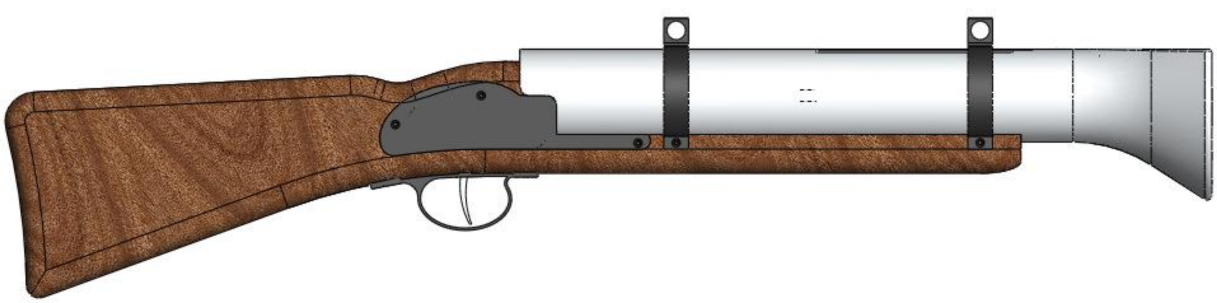

Fig. 20.21. BlunderBead Design.

TECHNICAL DESCRIPTION

The Blunderbead is pneumatically powered by a paintball canister of compressed CO2 contained within a backpack which our customer will comfortably be wearing during the 8 hour event. The air tank will have appropriate regulator and hoses which connect into an air powered solenoid that will control air flow. The solenoid is a 2 way 2 position valve which will allow the regulated air (< 200 psi) into the chamber of the air cylinder which will accelerate the rod a length of 4 inches within the barrel of the Blunderbead. The almost instant rush of air will launch the beads out at a comfortable yet forceful speed of nearly 20 meters per second. To operate the Blunderbead a trigger will be activated by the hook mechanism from the customer which electronically and mechanically opens the valve to the solenoid. Once the trigger is released the solenoid will open to atmosphere to relieve backpressure and allow the spring within the air cylinder to return the rod to its original unfired, ready position.

The Blunderbead will be locked into an angle of nearly 45 degrees by a carabineer attached to the belt straps on the backpack and a hook attached to the top portion of the Blunderbead's barrel located near the Blunderbead's center of gravity. A second strap attached to the backpack and slung around the customers' neck will be attached near the front end of the Blunderbead to maintain the desired angle and allow some slight adjustment. The eye hook attached to the front end of the barrel doubles as a lever which allows our customer to grasp it and swivel the device towards the vertical and load beads into the flanged (blunderbuss style) opening at the end. Once the customer has the Blunderbead loaded to their desired capacity, letting go of the eye hook will return the Blunderbead to the appropriate 45 degree angle for firing. This creates a free 'built-in' safety feature which disallows the Blunderbead to be fired while being loaded. Our customers hook mechanism must detach from the eye hook and move to operate the trigger.

Machined slots or holes along the top of the barrel will allow our customer to visibly see if the barrel is in fact loaded to avoid any mishaps. A mercury level switch will be installed within the wooden stock to only allow firing of the weapon when it's angled at the appropriate designated angle for safety. Firing will only be activated while the Blunderbead is angled at or above 45 degrees. The regulator on the air tank comes standard with a locking pin to avoid unsafe adjustments of the pressure entering the solenoid and air cylinder. The acquired regulator can be set and adjusted to operate from 40 psi to 200 psi. The air cylinder is rated to handle only 250 psi so the regulator becomes critical to the overall design and was factored into the trajectory calculations.

Overall the device prototype will cost roughly $1000. This includes all material parts and the machining of the aluminum barrel. All other work and crafting done is considered free labor done by the project team which includes wiring, wood cutting and small metal material shaping and cutting.

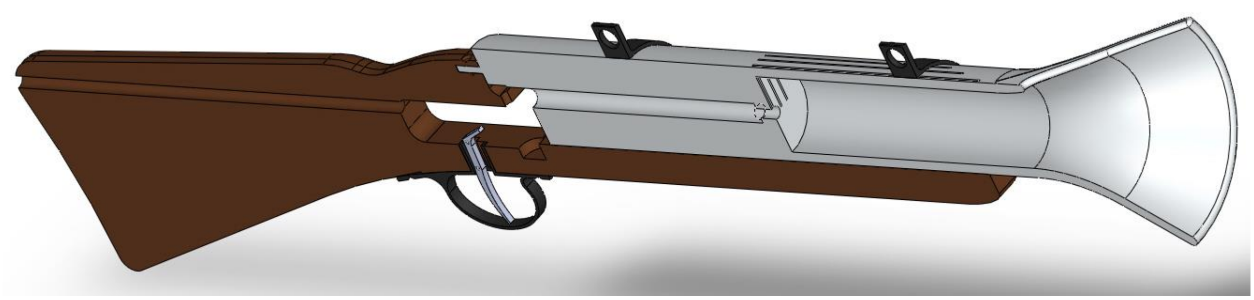

Fig. 20.22. BlunderBead Design Cutaway.

MOTOMED TRYKE

Designers: Solomon Kang, Joseph Pishery, and Mark Edmonson
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
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INTRODUCTION

Many people with disabilities attend physical therapy sessions and use rehabilitation devices to regain strength and mobility lost due to injury. One of the most useful devices for physical therapy is called the MotoMed (shown in Figure 20.23). The MotoMed is a stationary machine that has an available power assist driving mechanism in the pedals as well as the ability to give the user feedback on how much force is being applied on each pedal. Although exercising is an essential part of recovery, it only focuses on the physical aspect of rehabilitation. In order to promote a more recreational aspect of rehabilitation a tricycle was designed to help people with various disabilities overcome the emotional as well as the physical challenges of rehabilitating from an injury.

This tricycle is designed to be retrofit with components from the MotoMed while still retaining all of its functions. It is a challenging and complicated process to fit the original MotoMed components to a transmission system and frame; however, the advantage of having the full operation of the device is the focus for this design.

SUMMARY OF IMPACT

By taking the MotoMed and converting it into a tricycle, people with disabilities can rehabilitate while enjoying the freedom and leisure of having mobility outdoors instead of being confined to a room inside a hospital or gym. The idea is that a person who has been using the MotoMed can literally hop onto the tricycle and go for a ride because it is essentially the same device on wheels.

TECHNICAL DESCRIPTION

The MotoMed Tryke (shown in Figure 20.24) was created with the safety of the operator in mind, which is the strength for this design. Much of this project is to be custom fabricated using stock materials. This increases the cost initially, but if manufactured in large quantities the cost can be reduced significantly.

Fig. 20.23. MotoMed.

The estimated cost for this tricycle without the MotoMed components is just over $1200. The design of each major system on the tricycle was chosen carefully and meticulously. The following paragraphs will break down the different sections of the MotoMed Tryke and explain the components in detail. The frame is made of tubular steel that is bent and welded together. Steel was chosen over aluminum because this design is focused on the strength and aesthetics, as it features a solid front member that is welded to the rest of the body. This allows for a good looking curve in the front and most importantly a more stable structure. The stability and strength are critical factors considering the operator has limited control due to a disability. The frame can hold up to 300 pounds when fully assembled with other components.

One might wonder how the MotoMed Tryke steers with a solid front member. This problem is solved by a cable steering system. The handle bars are attached to cables which tug and pull on the front wheel through tension on a pulley. This allows for small inputs on the handlebar to be translated into larger exaggerated movements to the front wheel. Although this system has its huge advantages, it is an abstract design and is very uncommonly used which proved difficult to design in detail. The only tricycle we found that used this cable steering system was the A2B Tricycle for disabled children, which was developed by an engineer named Shabtai Hirshberg from the Hadassah College of Jerusalem in Israel.

In order to provide the operator with safer and easier access to the seat, a seat rotating mechanism was designed. The seat rotating mechanism uses a spring loaded cam and a notched rotor to provide five different positions in which the seat can be locked. The five positions are left, right, forward, 45 degrees from the left, and 45 degrees from the right. This mechanism will allow the operator to choose the best available angle to mount or dismount the tricycle. A challenging aspect of this design was making sure that the seat had enough clearance to swivel around without contacting any part of the frame or the wheels.

The transmission system chosen was a rear solid axle driven by a chain which is connected to the MotoMed's original motor. This design complicates the MotoMed's motor because it requires a sprocket to be attached on the inside of the motor housing to prevent interference with the pedaling. Another issue is the chain that could be exposed which can be a hazard if something gets caught on it. An easy fix is to make a cover for the chain, but it still needs to be accessible for routine maintenance. This was possibly the most challenging aspect of the project, and our team was not able to go into much detail for the placement of the chain.

The hydraulic brake system was chosen to be used for this tricycle for more stopping power. This is because the tricycle is fairly heavy and is motor driven, which would require a significant amount of force to come to a complete stop. Traditional bicycle brakes would indefinitely fail as it is made out of rubber. A single brake rotor and caliper system is attached to the rear axle to provide friction to the entire drive. Although the hydraulic brake system is advantageous in stopping power, it can also have issues of leaking and having to run fluid through lines along the frame.

Fig. 20.24. MotoMed Tryke.

THE ULTIMATE COLLAPSIBLE SHOPPING CART

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Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
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INTRODUCTION

Our objectives for this project are to create a collapsible basket for the wheelchair that is more user-friendly, easily maintained, and cost effective. This system is supposed to be designed for personal use, and to be simply attached to a certain existing brand wheelchair. By using parts that are durable, we are able to produce the ideal design, the Ultimate Collapsible Basket. This design project was to add a basket to an existing power wheelchair.

SUMMARY OF IMPACT

For a waist down disabled person, carrying a load over 10 pounds always has been a challenge. Our plan is to create a design that will allow the user to freely carry up to 50 pounds of load on the back of the wheelchair and also the advantage to do grocery shopping with peace of mind.

TECHNICAL DESCRIPTION

The Final design consisted of a Cart in tow. The cart is attached to the support column in the center of the power wheelchair. The jazzy Select is designed with an adjustable height seat. The seat is adjusted by moving along the length of the column. Our Cart is designed to fit onto this column by use of a collar. The collar is then connected by a pin connection to the rest of the frame. This joint is a hinge which allows the cart to rotate 180° about the base of the wheelchair. The Bag frame collapsed onto the frame of the device. The bag weight is supported by single castor wheel.

The Final design weighs approximately 24 lbs when collapsed. It has a carrying capacity of 25 lbs. The overall volume that it can carry is 0.67ft^3. A 12V DC linear actuator is used to open and close the basket. It moves at 0.79 in/s and has a 6inch stroke. The linear actuator s controlled by a three position rocker switch.

The final cost of the cart was $582.27. The cart is designed to be pulled in tow which allows the wheelchair to easily fit through doorways and smaller hallways. Allowing the cart to adjust to a sidecar position allows for easy access to materials in the cart. Wheels allow for more weight capacity. Some of the cons of the design are that it is rather large and heavy. A lighter more durable material would alleviate some of the weight issues. It also doesn't allow the user to move with it attached as a sidecar. The design also is difficult to attach for a person with limited mobility.

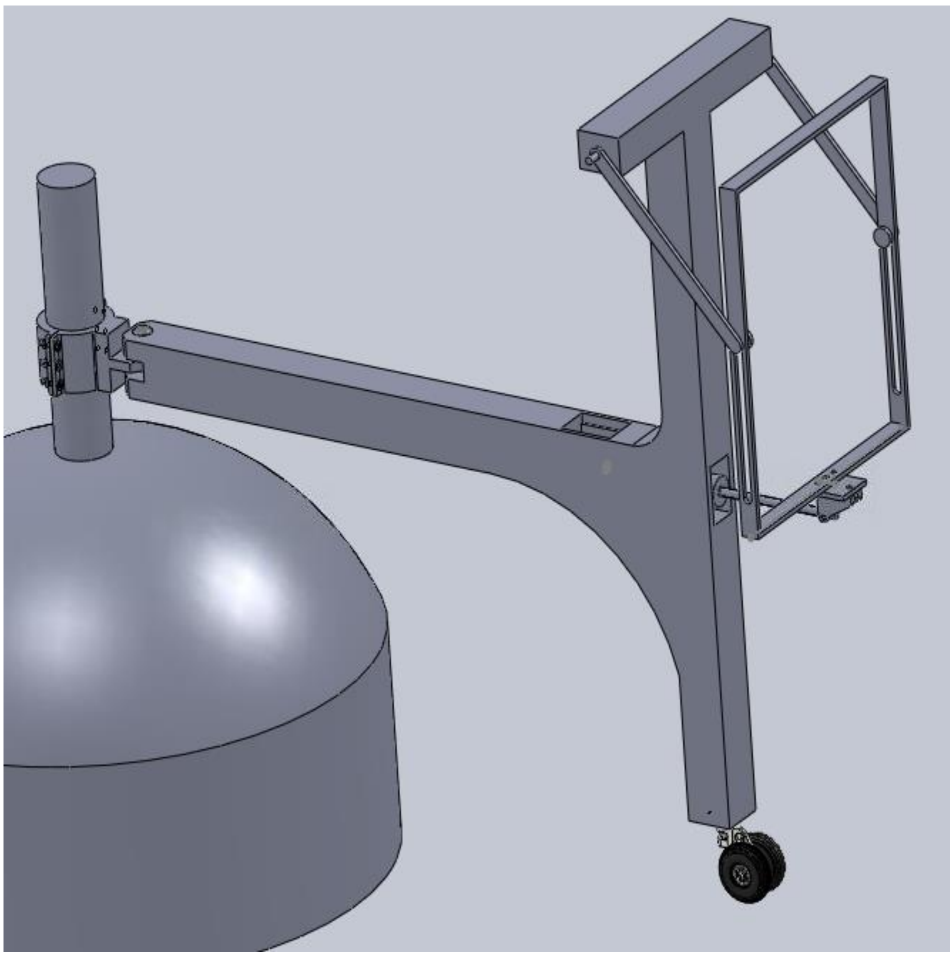

Fig. 20.25. Rendering of the Collapsible Shopping Cart.

MANUAL WHEELCHAIR POWER ASSIST

Designers: Michael Lewis, Curtis Neuman, Michael Werthman
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
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INTRODUCTION

Each year approximately eleven thousand Americans become paralyzed from spinal cord related injuries with a total of a quarter million already affected. Once this occurs, wheelchairs become the only mode of personal transportation available. For many, a manual wheelchair provides a feeling of self-reliance and freedom since their body power is still the only source of power. Unfortunately, manual wheelchairs are not without their disadvantages.

The traditional wheelchair requires the user's arms to start at an almost fully extended, downward position. The resulting movements of the arm transfer large amounts of stress to the shoulders. Numerous repetitions of this cycle lead to shoulder pain and wearing of the rotator cuff. Additionally, the user's hands must contact the moving wheel; push it forward, release, return their hands back to the original position, then start the process over again. This constant cycle is not only inefficient, dirty, and difficult on the hands; but is also a source of danger. There is also the common complaint among most users. They have a difficult time climbing ramps and moving along hilly terrain. This is because there is no way of increasing the leverage exerted on the wheel, or a way of changing the gear ratio.

We set out to design an add-on component that can correct these various deficiencies while not introducing any new ones. These deficiencies have been identified as being caused from two main problem areas. These areas are the lack of adjustable gear ratios or leverage; and the interaction between the wheel and hand, which is necessary for propulsion on conventional wheelchairs.

SUMMARY OF IMPACT

Our power assist has improved the quality of life of manual wheelchair users by allowing them to perform everyday activities with ease. In addition, our design requires less dexterity than traditional wheelchair propulsion mechanisms as well allow the user to use a larger muscle group to propel them forward. By using a larger muscle group, the user has more stamina and more power. We relocated the traditional hand grips mounted to the wheels, to handle bars that the wheelchair user has easy access to. This not only provides an added amount of comfort for the user but also provides a greater leverage arm to turn the wheel. This alone allows the user to get around easier despite us mounting an internal gear hub to the wheelchair wheel to allow the user to choose between different gear ratios. The design itself is very ingenious. We adapted existing technology from a bicycle and modified it to fit and work for a wheelchair. The design met all of our design requirements and is extremely compact and does not hinder any existing features of a standard manual wheelchair.

TECHNICAL DESCRIPTION

Our final design incorporated a completely manual power assist mechanism. In order to accomplish this we had to design between several gear reduction options. We decided to use spur gears or planetary gears for our gear reduction. Both are proven workable options but, in the end, we decided to go with a planetary gear setup because it is highly compact and exists in an already marketed product. As we researched, we discovered gear hubs for bicycles. This sparked our interests as it could be easily adapted to the wheel of a wheelchair and offers a unique approach to further wheelchair design. Bicycles are extremely versatile. They are able to cover just about any terrain you throw at them with relative ease due to a unique crank system and the availability to switch gear ratios. We decided that a perfect solution to our problem would be to adapt the principles off the propulsion mechanisms on a bicycle and apply them to a manual wheelchair. In order to accomplish this we were able to take some parts right off a bicycle and attach them to a wheelchair. However, we did have to custom design some of our own parts as well in order to fit the frame of a wheelchair and make it capable of a paraplegic or amputee to use.

This brings us to our second main portion of the final design which is the design of the propulsion system. Traditionally, manual wheelchairs are propelled by the user grabbing handles attached to the wheels and pushing forward with the wheelchair. Our solution is to re-design the propulsion system to incorporate handlebars that the user can push back and forth to propel the wheelchair and the user forward. The handlebars rise from the wheels and are located next to the user for comfort. This enables the user to use a larger muscle group to push the wheelchair as well as contains a power assist mechanism built in. The length of the handlebars themselves provides greater leverage on the wheels and therefore requires less force for the operator. One more aspect of the design we want to accomplish was to figure out a way to incorporate a dual drive mechanism into our design. We wanted the user to have continuous motion with the handle bars. For instance, when the user is going forward, the user would push the handle bars forward and also pull the handle bars back on the return stroke to provide another burst of forward momentum. We thought this would provide additional assistance as half the movements are needed to travel the same distance. In addition, if the user was climbing a hill, there would be constant forward propulsion and therefore no risk of the wheelchair rolling backwards. This is a huge advantage on its own over traditional wheelchairs as when using a standard wheelchair, when the user needs to take another grab of the wheel for another push forward that is nothing keeping the chair from rolling back. Essentially, the user loses a little forward gain with every stroke. In order to meet this criterion, we designed a crank mechanism that would translate linear motion into rotational motion. This turned out to be a hybrid between a crank mechanism in an internal combustion engine crossed with the pedal assembly found on an existing bicycle. We first designed a crank mechanism that would house a bearing to allow easy rotation and allow the sprocket to be attached. A sprocket attaches to the crank and a chain transports the power between the handle bars and the internal gear hub by connecting the sprocket of the crank to the sprocket of the internal gear hub. We used a simple linkage attaching the crank to the handle bars. We used our knowledge of Kinematics to design the length of the linkage by representing the handle bars, linkage, and crank as a four bar mechanism. The only thing left to design was a slight modification to the wheelchair frame. The internal hub weighs more than a standard hub as it contains internal planetary gears. With of the user in the wheelchair, the weight would put forces in the form of moments on the internal gears which would result in accelerated gear wear. We designed a support that attaches to the wheelchair frame that would support both sides of the internal gear hub. This would effectively eliminate all moments acting on the internal hub.

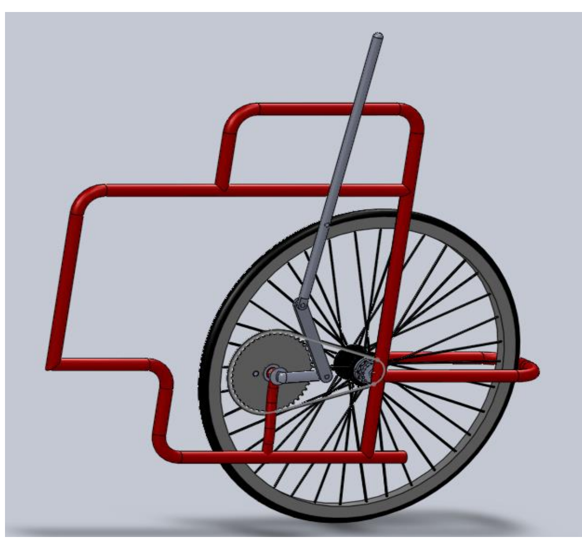

Fig. 20.26. Power Assist for a Manual Wheelchair.

HAIR SALON WHEELCHAIR LIFT

Design Team: Jeremy Baker, Kyle Hagen, Ryan Herron
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
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INTRODUCTION

There are 3.3 million people living in the U.S. that use a form of wheelchair for mobility assistance. Many of these people are unable to move in and out of their wheelchairs. Inventions have been made over the years to accommodate these individuals in living a healthy normal life. One place people go to on a regular basis is the hair salon or barber shop. A salon owner from Sarasota, FL has told Kyle Hagen the need for a wheelchair lift designed for use in a hair salon or barber shop. In a community dominated by the elderly, an invention of this sort would help the salon owner better serve this population. The customers would also emotionally benefit, as they feel a sense of excitement by being raised, lowered and spun around like a normal barber chair.

SUMMARY OF IMPACT

The goal of the project is to design a wheelchair lift that provides all the advantages of a barber chair. The wheelchair lift must easily rise up and down with variable height control. It must also have the ability to rotate completely. Keeping the stylist and barber in mind as well as the user, the design should allow the user to operate the wheelchair lift in the same manner as a barber chair.

In order to maximize the uses of the wheelchair lift, it needed to be light and portable. Being portable allows the stylists and barbers to transport the chair to and from assisted living homes or hospitals, reaching more customers. Finally, the design needed to be affordable.

TECHNICAL DESCRIPTION

With the completion of the prototype of the wheelchair lift, it is evident that there are certain areas which could be improved, although the concept is exactly how it was designed. If a client comes into a barber salon and is unable to move from their personal wheelchair into a barber chair then they are able to wheel up the ramp onto the wheelchair platform. From here they are able to be lifted to a desired height just as a regular barber chair. This not only gives the client in the wheelchair more mobility but allows the barber to work at a more convenient position.

Fig. 20.27. Photographs of the Hair Salon Wheelchair Lift

The final design for a prototype was chosen by collaborating many ideas and some trial and error making preliminary drawings on SolidWorks. The final design for the prototype was also based on parts readily available at no cost to the mechanical engineering department.

A large square deck was chosen to accommodate all types of wheelchairs and power chairs. Early research indicated that there are many types of wheel patterns and sizes for wheelchairs and power chairs. This deck is able to completely rotate on a heavy duty swivel built for large furniture, and ball transfer bearings for deflection. A spring hinged ramp is attached to the deck for rolling onto the deck. The lifting action is provided by a scissor lift design that allows for 12” of lift. The scissor lift design also has a low profile when at its base point. This was needed for the low clearance of power chairs. Saving weight and material, the scissor arms rest directly on the ground with ball bearings to allow motion. The input power is supplied by a linear actuator that was readily available in the mechanical engineering department.

Nearly all structural parts are made from 6061 T6 Aluminum, providing great strength and light weight. Bronze bushings are used for natural lubrication and protection at all points of motion between the aluminum and other steel parts. Calculations were performed for the scissor arms to ensure overdesign for safety. Due to over constraints, many stress calculations could not be accurately analyzed and failure testing of the prototype is needed to ensure safety.

The cost for the project materials can be broken down into separate sections. Since the entire structure was fabricated out of aluminum, the cost was $450. The linear actuator was readily available at no cost as previously stated. The only remaining factor for the project was nuts, bolts, and fasteners. Due to only being able to order bulk drove the cost of these parts up to around $250. This puts the grand total right at $700. When compared to a regular barber chair this price is actually very reasonable and would be easily marketed.

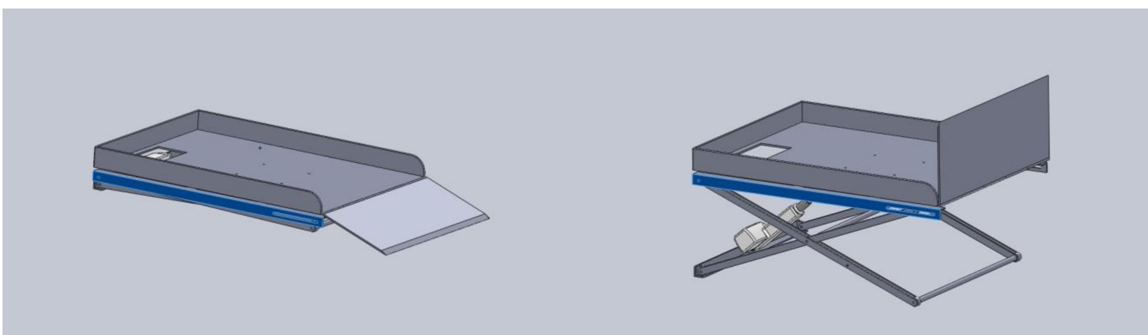

Fig. 20.28. Computer Renderings of the Wheelchair Salon Lift.

MINIMALLY INVASIVE MEDICAL DEVICE

Designers: Brandon Clark, Joel Cooper, Shaun DeSouza, Jon Kippert, and Dennis Walker
Consultant: Dr. Hart, USF Medical School
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
Department of Mechanical Engineering
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Tampa, Florida 33620-5350

INTRODUCTION

The task of this project was to design a minimally invasive medical device used for laparoscopic surgeries. This device should be small enough to allow suture free recovery and little to no scarring on the patient. The handle should be designed in such a way that it is comfortable to use, easy to manipulate and durable enough to last many hours of surgery. All the parts that are designed to go inside the patient must be made of FDA approved materials and hypo-allergenic to reduce risk during surgery. None of the features of the device should fail or break under normal use. Reduced recovery time, reduced risk of herniation, and non-scarring are all motivations for this project.

SUMMARY OF IMPACT

Shorter surgery time with less invasive techniques allows for a safer surgery, and a minimal risk of infection and non-scarring. This laparoscopic surgery instrument aims to have this type of impact.

TECHNICAL DESCRIPTION

Current mechanisms include an instrument that claims to be 2.3mm outer diameter when in actuality it is 2.5mm outer diameter. The main problem with this device is the handle which is hard to use for the surgeon, it is fragile, and it slips out of the patient during surgery. Another similar device is 5mm in diameter and requires a port in order for optimal use. The main advantage of this gripping device is the handle which most surgeons are comfortable using.

The device described here maybe broken down into three main groups: the Handle, the Probe, and the Clamp. The handle is rapid prototyped from a fused deposition molding process utilizing ABS plastic. The handle may be further analyzed into a parts assembly of the main handle, the trigger, and the slider. The main handle holds the probe tube and provides a track for the slider to transverse under application of the trigger. When the trigger of the device is

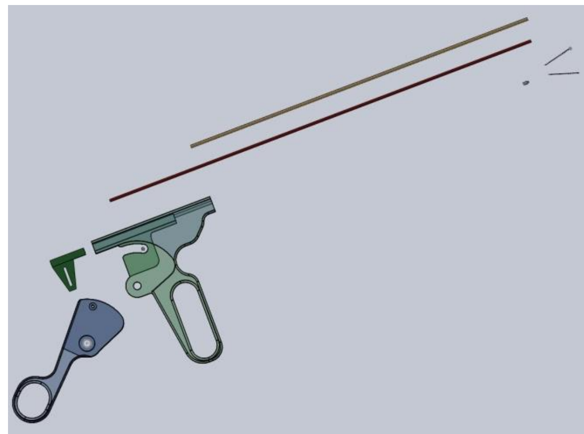

Fig. 20.29. CAD Drawing of the Minimally Invasive Surgical Device.

Fig. 20.30. Actual Prototype of the Minimally Invasive Surgical Device.

compressed, the slider is retracted to the rear of the device and the compliant mechanism is pulled and the forceps are forced inward. The compliant mechanism is able to be retracted due to an epoxy bond affixing it to the slider.

A compliant mechanism was used for the gripper instead of joints, which allowed for the flexibility needed without the risk of component failure. Using an argon laser welder to fuse the two pieces of the mechanism together allows for a surgical safe mechanism since no oxide layer is developed during fabrication. A large amount of work was put into developing an appropriate handle for the mechanism. The trigger is activated by the thumb of the operator which retracts the device into the tube, forcing the forceps to close. See Figures 20.29 and 20.30.

The project has been very successful as a full size instrument was developed. However, the design does have its flaws. The team did not implement a method to keep the tool inside the patient during surgery. During the prototyping process, Dr. Hart (the team's contact for device development) discovered a new problem with the device currently implemented in hospitals. (See Figure 20.31.) As the forceps are retracted to a close, they end up missing the tissue trying to be grabbed. This is a paramount problem that has frustrated surgeons to the point of not using this minimally invasive device. The team plans on implementing a secondary inner tube that moves instead of the gripper. The cost of the parts and material is very difficult to estimate at this time.

Fig. 20.31. Tip of the Minimally Invasive Surgical Device.

OFF ROAD MANUAL WHEELCHAIR

Designers: Alexander Keever, Andrey Kharitonenko, Justin Harrison, Oscar Levy, and Jacob Lashley
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
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INTRODUCTION

The task of this project was to design an off road mobility device that can be used and operated by a user with limited lower body function. The device must be manually driven by the user. In order to limit the scope of this task, we chose to focus on a beach environment. This environment is assumed to have a relatively flat terrain mostly made of loose sand. This was chosen because one of the most popular outdoor locations in Florida is the beach.

SUMMARY OF IMPACT

This design should greatly improve the quality of life and open new options for users. The manual drive should help users develop strength and self-confidence as they are able to interact with more of their environment and perform the same activities as those without similar impairments. The users will not be reliant on caregivers, allowing an increase in independence and positive self-image. The size limitation we are applying to this design will also make it possible for the user to utilize this device as his or her primary wheelchair. This will simplify a user's choices for outdoor activities.

TECHNICAL DESCRIPTION

Generally, there are three main options for "off-roading" for wheelchair users: using a motorized mobility device, an interface platform for his or her normal mobility device, or relying on someone else to help them. The first form is essentially an electric wheelchair with upgrades to the motor and tires. The main problem with this approach is that it is extremely limited in its potential since most are built off standard electric wheelchairs. This means they are rarely capable of providing much more clearance than normal chairs. The second approach is to use the user's normal device to interface its drive wheels with an off road platform. The downside to this is that the platforms tend to be much larger than a standard wheelchair. This presents indoor accessibility issues for users and often prevents them from being able to move in tight spaces. The third approach involves relying on a caretaker or assistant to push the user around in a push wheelchair with larger wheels intended to be more accommodating for outdoor terrain. This approach is severely limiting because it takes away the user's independence.

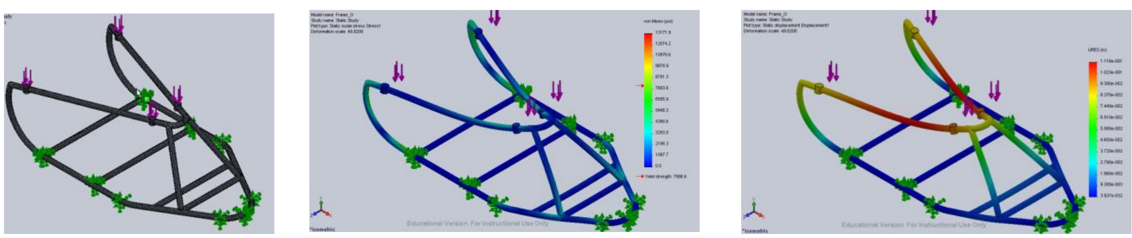
Fig. 20.32. CAD Drawing of the Off Road Manual Wheelchair.

The final design is a self-propelled outdoor terrain vehicle designed for optimal use for a person with a lower extremity disability, with these features: completely manually driven, not requiring much more space than a standard wheelchair, and not requiring any assistance from a care giver. It incorporates the use of a bench-press power plant that transfers power to the wheels via crank rocker. A crank rocker was chosen as the final design due to its ability to increase mechanical advantage, provide a longer power stroke, and allow the user to easily change directions. Two crank rockers are used to propel the vehicle with each rocker independent from the other. This allows the user to turn by providing more power to one side compared to the other allowing for exceptional mobility especially at slow speeds. A typical wheelchair provides a limited impulse of torque for every stroke and each stroke is only in one direction. A user must propel their wheels directly with their hands over a small distance. This equates to a very limited amount of power per stroke making travel over rough terrain difficult and over sand near impossible. What is needed is more power per stroke. The final design increases the amount of torque of a normal wheelchair by 24%. This is sustained over a longer duration per stroke than a standard wheelchair, both outward and inward. Each stroke in the final design includes an outward push from the user as well as a pull backward in order to roll over the crank rocker's change point.

Large bike tires, twenty nine inch diameter mountain bike tires, were incorporated in the final design. Deep groove treads allow the vehicle to dig into soft sand and maintain stable traction. A six inch castor was also added in the back for stability and ease of motion. Since excessive vibration can occur from outdoor use, three shock absorbers were added beneath the seat in order to filter out high frequency vibration and dampen shock. 6061-T6 extruded aluminum tubing was chosen as the main frame material due to its reputation for ideal strength and durability in a light package. Round tubing also allows for a sleek, modern design as opposed to square bar stock. See Figure 20.32.

Also, the frame is well supported and designed with a safety factor of two for a two hundred pound individual. This safety factor was confirmed through finite element analysis in yielding, strain, and column buckling, as shown in Figure 20.33. Areas with high levels of stress concentration were reinforced with supporting linkages of redundancy.

The cost of the parts and materials is estimated to be $925.



(a) 2 FEA Mesh (b) 3 Stress Analysis (c) Buckling Analysis

Fig. 20.33. Finite Element Analysis of the Off Road Manual Wheelchair Frame.

WHEELCHAIR SLIDING SEAT

Designers: Nicole Birchell, Christian Giron, Daniel McConnell, Cory Nation, and Jonathan Todd
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
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University of South Florida
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INTRODUCTION

There are currently an estimated 1.6 million Americans who use a wheelchair on a daily basis. Completing even the simplest daily tasks for these individuals can be a challenge. Many of these tasks require transfer from their wheelchair to another area, such as a bed or vehicle. Often it helps to have an extension of their chair to help them move. Currently the most popular method is sliding on a wooden board. This accessory must be kept either with the user or at the location of use. This extra bulk is considered a burden by wheelchair users and causes interference with their everyday life. The desire for a wider range of accessible area with using only a wheelchair drives the motivation for this project.

SUMMARY OF IMPACT

This device is meant to be a permanent fixture for a wheelchair which extends its usable range without moving the base of the chair. If the seat can remain attached to the base yet extend into a nearby area, it could eliminate the need for loose accessories and create a greater ease of motion for the user during transfer.

TECHNICAL DESCRIPTION

For the purpose of this design, we have made the assumption that this product will be used by people with sufficient upper body strength and range of motion. This is to say that they will be able to propel themselves away from the base and towards their destination. While this design is manual, there is a possibility that future endeavors will make the slide powered.

First, the primary goal is to have a permanent seat slide away from the base of the chair. Another important feature, yet to be developed, is adjustment at the end of the extension. Once the chair has been extended into a more useful range, the ability to adjust the position of the user is crucial. Usage can be limited if there is no way to orient the user into an

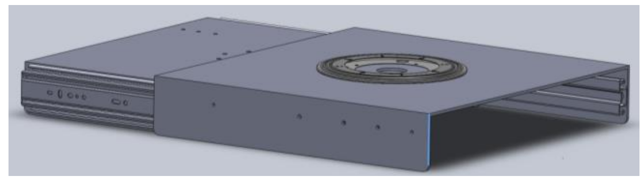

Fig. 20.34. CAD Drawing of the Sliding Seat.

easy and acceptable position. Also, if there is no adjustment at the end of the seat, then the user may rely of the movement of the base for adjustment. This is unsafe and also defeats much of the purpose of this design.

From the prospective of the user, they are for the most part confined to their wheelchair for much of their day. Being able to leave the chair to a more inviting surface like a bed, chair, or sofa is something that would be desirable whenever it was accessible. For electric wheelchair and manual wheelchair users this can be a nightmare without some sort of plank (usually wood) to bridge the gap or in some cases they would need another able bodied individual to assist them in the move. With our prototype, it will eliminate the extra "plank" element and in some cases the extra individual. Basically the "plank" has been transformed in to a mechanical mechanism that has been built into the wheelchair. Our current prototype only focuses on the electric wheelchair, but a redesign in the future for a manual wheelchair is not out of the question. The CAD drawing and a photo of the prototype can viewed in Figures 20.34 and 20.35.

To operate the prototype sliding seat, the user needs to maneuver the wheelchair to a parallel position at least 20 inches away from the desired surface. Making sure that the desired surface is on the side of the wheelchair that slides out. Then the user simply unlatches the sliding mechanism and slides over to the desired surface. To leave the surface, the reverse is done. It is understandable that some places are more difficult to maneuver an electric wheelchair to a position so the sliding seat can be utilized correctly. Therefore, we have introduced the feature of a turntable to allow the maximum angle allowance. This may come in handy in some rooms that are smaller or narrower.

Overall, the effectiveness of this prototype is very high. It has the ability to change the lives of electric wheelchair users drastically. This sliding seat prototype gives the user another level of independence and individuality in a world where they usually require the assistance of others.

The cost of materials for the prototype was a little on the expensive side, however the materials were over designed to make sure we had a working model. The cold-rolled steel used for the base of the sliding mechanism was 3/16" thick and can be reduced to save cost and weight. The steel the sliders may have been a little over designed but they are rated well over the average weight of a human to make sure they did not hinder the design. The design also incorporated the use of two turntables and several types of hardware to attach it firmly to the fixture.

The cost of the parts and materials is estimated to be $250.

Fig. 20.35. Prototype of Wheelchair Sliding Seat.

ROTATIONAL AND SLIDING SEAT MECHANISM

Designers: Scott Padilla, Kyle Hanrahan, Mark Marchese, Nick Stephenson, Igor Markovic
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
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INTRODUCTION

Since the time the motorized wheelchair was originally invented, for the purpose of assisting injured World War II veterans, many upgrades and advancements have been made to the field of assisted mobility. These advancements have ranged from designing a quicker and more power efficient motor to even designing wheelchairs with the ability to traverse up stairs; however, the aspect of aiding persons with disabilities in the transition from their chair to other locations needs improvement. If a wheelchair user wants to leave the chair, without the assistance of a second person, separate products must be purchased. These products can assist the user in their transition from their chair to a second location, but this movement from a wheelchair can be very perilous.

SUMMARY OF IMPACT

Our design team believes that, although there is room for improvement and work still to be done on the design before it can be considered a finished product, this device has a great capacity to help wheelchair users. We believe it has the potential to eliminate the need for purchase of separate handrails and other such devices that are currently used to facilitate users transitioning from their chair and moving to another location.

TECHNICAL DESCRIPTION

A CAD drawing is shown in Figure 20.36 and the completed prototype in Figure 20.37.

Connected to the pillow block is the single aluminum guide rail that guides the linear motion of the lead screw which actuates the mechanism. A cylindrical cover is placed over the rotational base and a pin is used to adjust and fix the direction the chair is facing. A special mount was created to attach the mechanism to the chair that was used in the prototype.

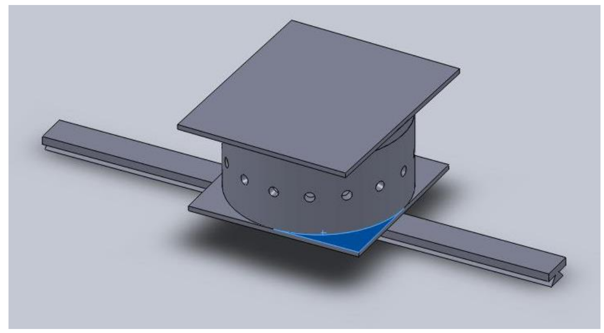

Fig. 20.36. CAD Drawing of the Rotational and Sliding Seat Mechanism.

The prototype met all of the guidelines and requirements we as a team decided were important, and exceeded many of our expectations when it came to performance. "Field tests" were performed by our group members individually to determine how helpful and easy to use this design would be for a wheelchair user. We believe it has the potential to eliminate the need for purchase of separate handrails and other such devices that are currently used to facilitate users leaving their chair and moving to another location.

Total costs for the prototype were very manageable; with the linear slide and pillow block only costing slightly over one hundred and thirty six dollars. More advanced slides, can cost upwards of three thousand dollars for seventeen inches of linear motion.

The cost of the parts and materials is estimated to be $231.

Fig. 20.37. The Rotational and Sliding Seat Mechanism Prototype.

OFF-ROAD HOVERCRAFT

Designers: Gerald Daun, Olga Ramos, Chris Hages, Roberto Fung, Thomas Driscoll
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
Department of Mechanical Engineering
University of South Florida
Tampa, Florida 33620-5350

INTRODUCTION

Persons with disabilities have difficulties navigating any rough terrain and there are not many alternative wheelchair options available for them. The team approached the project by trying to create a product that did not have very much direct competition in the market. This was facilitated by designing a hover powered vehicle instead of a tracked or wheeled vehicle, of which several are available on the retail market. The hovercraft design would allow for higher top speeds and maneuverability while providing a stable platform to store the rider and multiple objects.

SUMMARY OF IMPACT

This design has not been fully realized at this time but the impact could be significant to those with disabilities wishing for more mobility and enjoyment in the form of an easily operated vehicle. The design could be very useful if built to the specifications as it would enable people with lower body disabilities or maybe even more debilitating injuries to traverse rugged terrain easily and also venture out into the water with their personal mode of transportation.

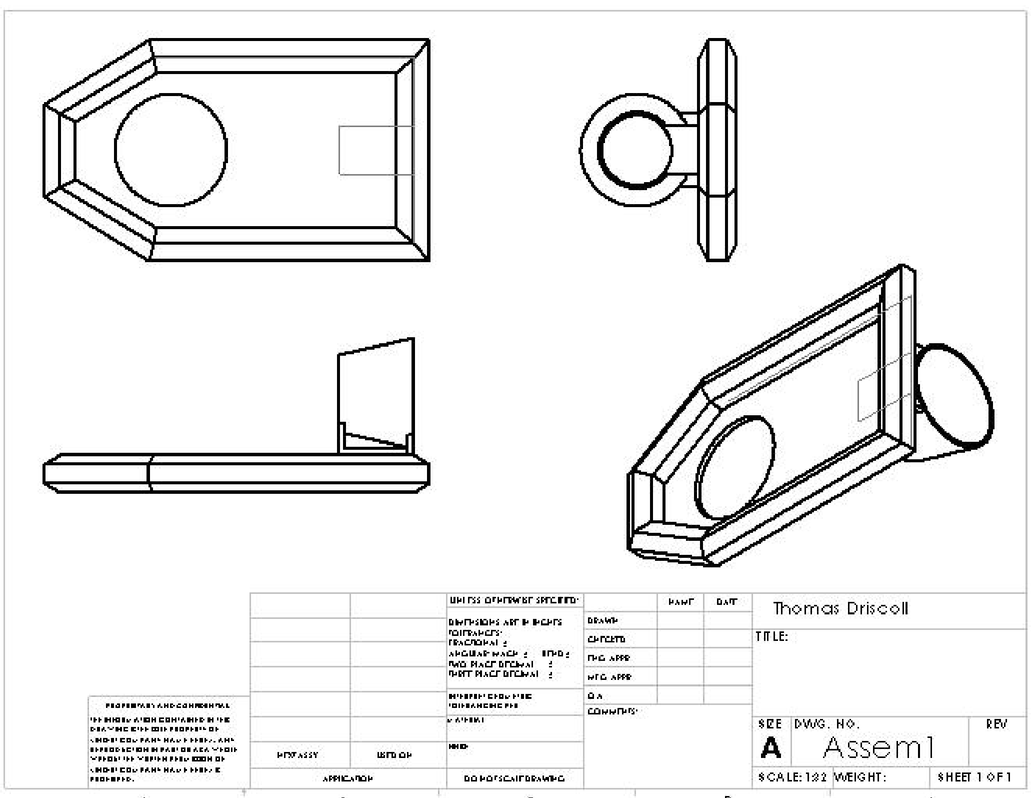

Fig. 20.38. CAD Drawings of the Off-road Hovercraft.

TECHNICAL DESCRIPTION

Off-road wheeled vehicles can be difficult to operate and may not be accommodating to persons with limited upper body strength. The design proposed would have easily operable hand controls that anyone could operate with little training. There would also be a multitude of safety features similar to those on current products.

The outside base of this hovercraft was designed to be created out of Hypalon®, a flexible synthetic rubber material that has been proven to have excellent air holding capabilities and oil resistance. The inside of the base would then be covered in fiberglass to make it airtight and flexible. The design incorporated a dual engine system. One would be used to lift the craft by forcing high pressure air under the vehicle and the other would drive the turbine that would provide the means of propulsion.

The user's seat would be situated in the center of the craft and would be operated solely by hand controls. Safety concerns would be addressed by adding a roll cage for stability and protection in case of tipping. Ideally the seat would be ergonomic and adjustable, adding support and comfort for a wide range of individuals. The vehicle would contain compartments and storage for multiple functions to add versatility. See Figures. 20.38 and 20.39.

The total for all of the supplies used to create the prototype comes to just around $400. If labor and assembly costs are added in however the total could climb easily to $1000-$1500 for the numerous man hours spent in construction. The estimated cost to create a fully developed off-road hover buggy is estimated at somewhere from $6,000-$8,000. With adequate mark up for profit margin the retail cost could easily be in the $8,000-$10,000 range which is competitive with current wheelchair prices.

The cost of the parts and materials is estimated to be $400.

Fig. 20.39. Initial Prototype of the Off-road Hovercraft.

MIKE: THE OFF-ROAD VEHICLE

Designers: Andrew Abney, Kathleen Boland, Garrett Gregory and Brandon Halbert
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
Department of Mechanical Engineering
University of South Florida
Tampa, Florida 33620-5350

INTRODUCTION

Wheelchair users' outside excursions are often limited to paved roads. Our project was designed to meet the need of extending the ability of manual wheelchair users to off road environments. Many of the current off road offerings require the user to have someone push them around. The design we used allowed for the user to power the chair without assistance. We designed our device with the specific audience of beachside resorts, who under ADA law, must provide a means for those with disabilities to gain access to the beach. Building expensive boardwalks out to the beachfront to accomplish this would incur a large maintenance cost. Our design allows the user to move them by mounting their wheelchair to a platform that will translate motion inputs to the wheelchair into motion on the ground.

SUMMARY OF IMPACT

This project greatly frees manual wheelchair users when they are at the beach. By combining the ability to freely explore the beach with an interface that the wheelchair user is already familiar with, this device grants the end user with a way to relax and explore areas they could otherwise not go. The convenient interface allows the user to focus on the enjoyment of the beachside area. This will also solve many problems for the resorts because it frees their funds from building costly boardwalks.

TECHNICAL DESCRIPTION

Our project accomplishes the goal of beachside access for those with disabilities through the use of a platform to which their wheelchair attaches. Once on board the platform, the user's wheelchair will sit in a pair of rollers. One of these rollers will move freely; the other will be part of the drive train. This roller will be geared to an axle that will power the drive wheels of the platform, located in the back. At the front, casters will be mounted to allow for ease of turning. The wheels used are specifically designed for beach use, and help the user get traction and prevent sinking into the sand. Our prototype will use steel gears and an aluminum frame with pillow block bearings for the axles. This will be changed in the final design to a stainless steel frame with integrated drive train so that smaller, higher quality material gears may be used. See Figure 20.40.

Initial analysis shows that getting onto the platform can be cumbersome under the user's own power, but is possible. This product will be put in use at resorts with the help of staff for ingress and egress.

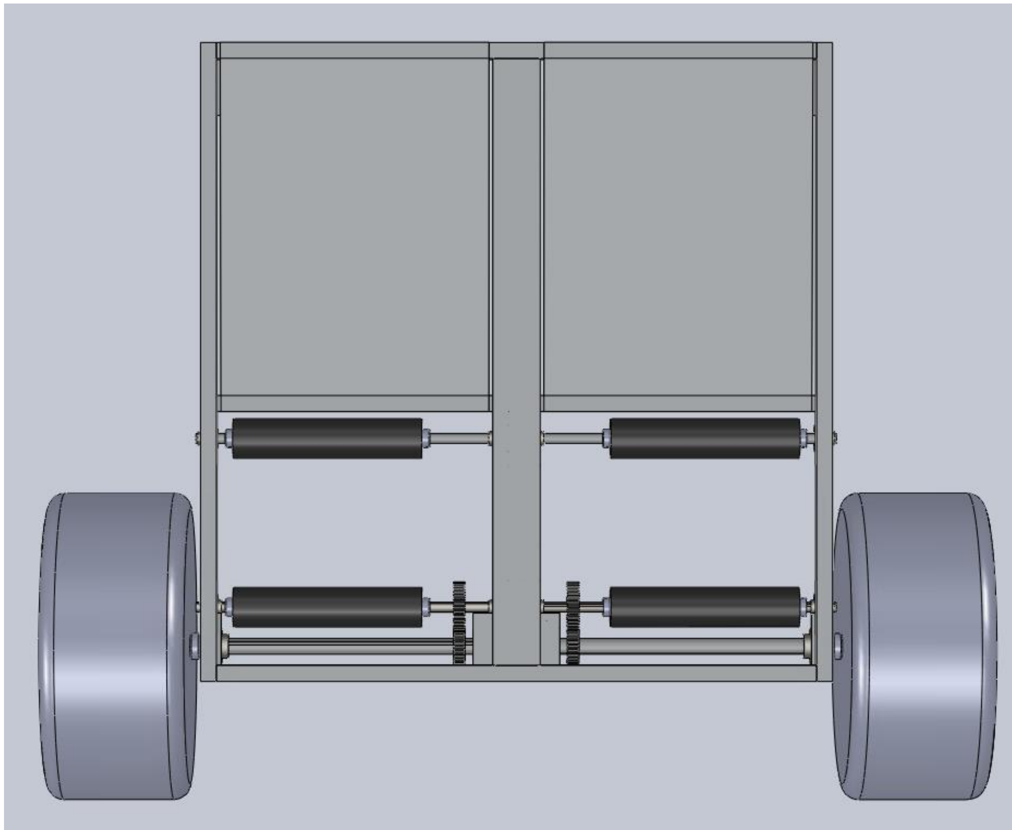

Fig. 20.40. CAD Drawing of the Off-road Manual Wheelchair Platform – Bottom View.

OFF ROAD MANUAL WHEELCHAIR

Designers: Peter Falvo, Richard Haynes, Jason Smith, Alejandra Vega and Jean Pierre Zola
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
Department of Mechanical Engineering
University of South Florida
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INTRODUCTION

An off road manual wheelchair was designed and built as a Capstone project for the Mechanical Engineering Department at the University of South Florida. The chair was designed for an active 95th percentile male that would be able to ride around a city/town environment but not be limited to sidewalks only. In other words, the off road manual wheelchair would be able to endure terrain from pavement to grass, gravel, trails, dirt, etc. Some of the characteristics that were taken into consideration in the design process were: compactness, propulsion and ease of use. The design was kept simple while trying to achieve the different design considerations. The main feature of the wheelchair is a four bar mechanism that aids in wheelchair propulsion.

SUMMARY OF IMPACT

The intent of this wheelchair is to increase the mobility of the user by using mechanical concepts. It is well known that common type wheelchairs are ineffective in transferring all the power given by the user and therefore, over long distances, the process of propelling the wheelchair is tiring. To counteract this problem, one of the mechanical concepts that this design implements is a four bar mechanism to transfer the power provided by the user. The off road manual wheelchair aims to provide the user with the freedom to go places that would be very difficult, if not impossible, to get to in a regular manual wheelchair.

TECHNICAL DESCRIPTION

For the propulsion mechanism, there were two mechanisms that were proposed: a crank and a four bar mechanism. The four bar mechanism was preferred over a crank system because the four bar mechanism follows an elliptical pattern rather than the circular motion of the crank system. This elliptical pattern maximizes the range of motion that the user's arm travels when compared to the range of motion of the crank system.

The drive train that was used was adapted from two children bicycles. The bicycles were selected because the rim and tires that were used are the adequate size to achieve the desired height of the wheelchair. These bicycles were also used because they could be modified easily and they had many components that were needed for the off road manual wheelchair. Some of the components that were useful were the gear system, the brake system and the rear swing arm of the bicycles.

By utilizing two bicycles, the possibility of having an independent drive train for each wheel was feasible and the maneuverability desired was achieved. One of the advantages that the independent drive train provides is the ability for the user to turn as desired without having to utilize a steering mechanism. For example, if the left side propulsion mechanism of the wheel chair is driven with more power, the wheelchair will turn to the right and vice versa. Since the off road manual wheelchair has an independent drive train, the braking system needed to be independent for each wheel to support the purpose of having an independent drive train mechanism. The V-brakes available from the bicycles were installed on the wheelchair so that the user could slow down and stop at their own discretion. The independent braking system allows the user to do sharp turns if needed. Sharp turns are useful in cases where the user is confined to a tight space or wants to avoid an obstacle. The braking system also includes a parking brake feature.

The wheelchair has two main wheels, which were taken from the bicycle system and are the main support of the wheelchair. They are located close to the center of gravity of the user. Two caster wheels on the front of the frame were added to prevent the user from tipping forward, which is possible when driving the wheelchair on rough terrain. The terrain that the wheelchair is intended for might be uncomfortable for the user; therefore the wheelchair is equipped with a suspension system on each drive wheel. The two main wheels are supported by the swing arms used off the bicycles. The rear suspension from the bicycles was modified so that it could be incorporated into frame of the off road manual wheelchair providing comfort to the rider. The hubs of main drive wheels included cassettes which are able to free spin; making maneuvering the wheelchair down an incline easier.

The frame for the off road manual wheelchair was custom made to fit all of the mechanism previously described and provide stability. The frame was made of one inch square extruded Aluminum T6-6061, which is very strong and durable. The frame was TIG (tungsten inert gas) welded at all of its critical joints by a professional welder. The TIG welding process was chosen because it grants the operator greater control over the weld than competing processes resulting in stronger, higher quality welds. All fasteners used to bolt components onto the frame were of adequate strength. See Figure 20.41.

The frame did not turn out to be the dimensions that are specified by ADA requirements. Nevertheless the off road manual wheelchair is intended for an outside environment where the only thing that should be an obstacle is nature and not manmade structures. The off road manual wheelchair frame is designed to fit a universal tractor chair for the user to sit on. The tractor chair was donated to our group and therefore was implemented in the development of this project. The chair is tilted at an angle of about 10 degrees so that the user feels more comfortable sitting on the chair and aids on the propulsion process.

One thing that needs to be looked at in more detail is the four bar mechanism. Our design was functional but wasn't the best method in transferring rotational power into translational power. Finding a different fastener instead of the rod end bearings is a must because there was too much play when rotating the four bar mechanism. Another thing that needs to be focused on is the poor quality of the pillow block bearings we purchased. This item also had too much play in it when trying to rotate the four bar mechanism. If we had more time, we would also redo the frame and use a jig so that all mounting surfaces would be level to the ground as well as the straightness of the swing arms. One thing that is crucial is having a tensioner on the chains so that when the rider hits a bump the chain itself doesn't lose slack and pop off the sprocket. We also need to improve the method that the rider uses to get in and out of the chair; right now the four bar mechanism interferes with transfer. The cost of the parts and materials is estimated to be $620.

Fig. 20.41. Off Road Manual Wheelchair Prototype.

COMPOSITE WHEELCHAIR DESIGN

Designers: Kimberlee Fraser, Sean Meibers, Christopher Nelson, Nathan Shinn, Tahiem Williams
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
Department of Mechanical Engineering
University of South Florida
Tampa, Florida 33620-5350

INTRODUCTION

The purpose of this project was to design an innovative manual wheelchair made with composite materials. This wheelchair design was built specifically for an active adult user in order to simplify the initial design process. Further design considerations were made to take advantage of modern composite materials, such as carbon fiber, and give a new look to the wheelchair without being overly dramatic. Use of composites would allow for a reduction of weight, and therefore fatigue for the user. Likewise, the new look was born out of input from the industry and users. The use of titanium has allowed for lighter wheelchairs but with similar designs repeated over and over.

SUMMARY OF IMPACT

The project created a lightweight composite wheelchair with a minimalist design that would add to not only the appearance of the chair but also to the maneuverability of the user. Maneuverability means the user has easier access to areas while the lightweight design means that less effort is expelled in moving the chair and therefore adds to the ease of getting around. The flowing design of the frame itself sought to provide a new look that was a step away from what is nearly always seen in industry while not drawing attention to the chair. These advantages, along with others such as the open design of the spoke-less wheel, not only maintains the minimalist design but also opens up the possibility for easy access to storage under the seat from the side of the chair; all aim to add to the enjoyment and use a user would get out of his/her wheelchair.

TECHNICAL DESCRIPTION

The final prototype design can be broken into three main design elements: 1.) the frame, 2.) the spoke-less drive wheels, and 3.) the spherical caster wheel. Each component is a unique alternative to the industry standards and offers several advantages over currently available products. The frame of our final design is best described as organic; lacking some of the right angles and sharp edges of current wheelchairs, particularly where structural components meet. Whereas traditional tubular frames are generally joined by welding together straight pieces of steel or aluminum at angles that create sharp transitions, our frame employs large radius fillets between structural elements. This results in a striking aesthetic that gives the impression of the design being made of one continuous part while simultaneously reducing stress concentrations. See Figure 20.42.

In addition to its graceful form, our frame is designed to maximize maneuverability. The frame combines a narrow width with a shorter overall length, and along with the forward caster wheel this enables users the freedom to navigate tight spaces more easily. Furthermore, this minimalist design combined with the use of carbon fiber results in a frame that is lightweight. Based on volume analysis in SolidWorks it can be estimated that the frame's weight alone would be 2.3 pounds. This compares well to current titanium wheelchairs which weigh about 10.5 pounds.

The spoke-less wheel is the second major component of the composite wheelchair design and includes three main components of its own: the 1.) outer wheel, 2.) inner frame, and 3.) bearings. The outer wheel is designed to operate much as it would in a regular wheel except that it would run around a second circular inner frame. The inner frame would only be slightly smaller than the outer wheel, fitting inside and partially enclosed by the wheel. This would be accomplished by manufacturing the outer wheel in two parts that would then be assembled around the inner frame and locked into place through several bolts. The inner frame would then connect to the main body of wheel chair through three brackets that would allow for lateral adjustments so that a user could customize the balance of the wheelchair. Ultimately, the open space afforded by this design not only added to the minimalist look of the main frame but also opened up options for storage beneath a user's seat that could be reached from the side of the chair.

Between the inner frame and outer wheel would be a series of bearing surfaces. Currently these bearing consist of 40 alternating bronze barrel bearings. They contact the wheel on angled surfaces, providing the bearing support while acting to keep the wheel centered into the frame. While the bearings would be made of bronze, the frame would continue the use of carbon fiber with the brackets being made of titanium so as to keep the weight of the wheel to a minimum.

A caster wheel for the front provides full rotation for the user and allows them to get around with little effort. The bottom of the caster wheel will be made flat to increase the contact area, giving the user more control and stability. The flat wheel also prevents the user from getting stuck in small and large cracks, and it allows the wheelchair to operate on different terrains. Furthermore, the placement of the caster wheel raised the chair, raising the eyelevel of the user. For the design, a Baron Wheel Caster manufactured by Shepherd Caster Corporation was chosen. The caster itself is made out of aluminum while the three inch diameter rubber ball is made of polyurethane. Polyurethane was chosen as it has superior impact and abrasive resistance compared to other rubbers. The material selection will ensure that the caster wheel will be durable and safe.

With regards to the overall design, several concerns were identified. One dealt with the manufacturability of the wheelchair. Carbon fiber is difficult to manipulate and form, so the fact that the design includes many organic shapes might hinder its large-scale manufacturability. Furthermore, while customizability was considered during the course of the project, limitation meant that they could not be implemented and currently the wheelchair only comes in a single size. Additional concerns arise around the spoke-less wheels. Their complexity could lead to difficulties in finding a skilled professional to work on them if repairs are needed. Furthermore, the added thickness of the wheel does increase its weight and further designs should strive to reduce this. It should be noted though that the frame could be modified so as to operate with a standard set of wheelchair wheels. Despite these drawbacks, the design does succeed in its key areas. It provides a lightweight, composite material wheelchair that offers a unique visual appeal. Additional benefits, such as the ability to reach under the chair from the side and the maneuverability gained by the frame shape and caster wheel, add to what a user is able to do and the overall value of the chair. The cost of the parts and materials is estimated to be $6000.

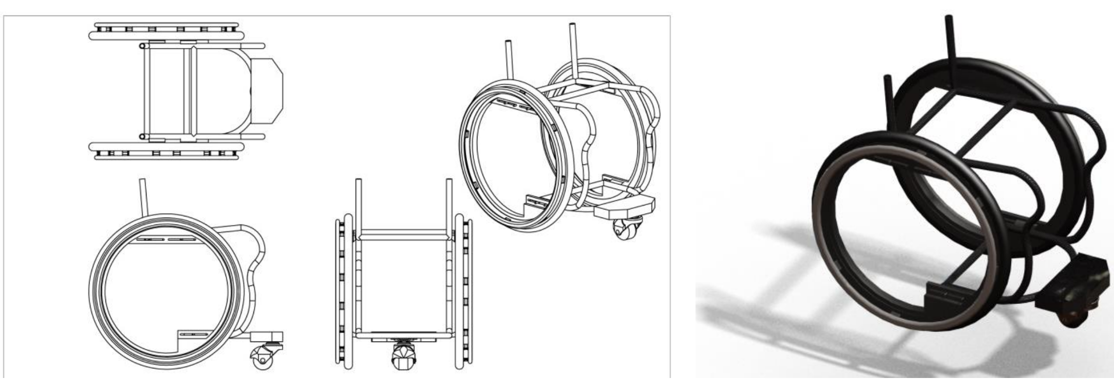

Fig. 20.42. Manual Wheelchair CAD Drawings and Prototype Made from Composite Materials.

OFF-ROAD MANUAL WHEELCHAIR

Designers: Vincent Shatlock, Ryan Uchida, and Joseph Wirth
Supervising Professors: Dr. Don Dekker, Stephen Sundarrao
Department of Mechanical Engineering
University of South Florida
Tampa, Florida 33620-5350

INTRODUCTION

In this project, the challenge was to create a wheelchair that is capable of operating on terrain that traditional wheelchairs cannot, such as grassy fields, dirt hiking trails, and even sandy beaches. It was stipulated that the product must be manually-powered, with the only mechanical input coming from the user. Because the design is primarily intended for use by people with limited or no use of their legs, all primary functions – driving, braking, and steering – must be able to be operated by the hand and arms, and must be able to be performed simultaneously. In addition to these constraints, the intention was to create a product that doesn't look or feel like a standard wheelchair, to allow users with disabilities to feel as if they weren't in a wheelchair, and also to expand the potential user base to include people without disabilities. The resulting product looks more like a hand-powered adult tricycle than a wheelchair.

SUMMARY OF IMPACT

Through the use of this off-road manual wheelchair design, people with disabilities will be able to explore the outdoors, and traverse areas that were previously off-limits to traditional wheelchairs. The mountain bike drive tires give the chair better traction on grass or dirt than standard wheels would, and the mechanical advantage gained through the lever-chain drive system allows the user to apply greater torque to the drive wheels, giving the chair the capability of overcoming inclines and bumpy terrain more easily than hand-grip wheels. The independent left-right drive system gives the user similar driving and steering control as they would be accustomed to from use of their normal wheelchair.

TECHNICAL DESCRIPTION

The final design is a three-wheeled chair; two 26″ drive wheels in the front, and a single 8″ wheel in the rear. Bicycle wheels with off-road tires were used to drive the wheelchair and a lawnmower wheel was user for the rear, to increase traction and stability on the intended terrain. The welded frame was constructed of 1″ square tubing and 1.25″ round tubing, all steel.

The drive system was created using several bicycle parts. Single-speed freewheel hubs were mounted on each wheel, and were connected by chain to a pair of sprockets from a bicycle pedal assembly. A long handle was mounted on each sprocket, with handgrips and brake levers on other end. The result of this layout is two completely independent drive wheels. The user has the ability to drive or brake the left or right wheel independently, or simultaneously. Due to the freewheel hubs, only the forward stroke on the handles transmits torque. This is beneficial for both function and safety. From a functional standpoint, the user is able to steer by driving one wheel and allowing the other to freewheel. An input to the left wheel alone, with the help of the rear swivel wheel, turns the chair right, and an input to the right wheel alone turns the chair left. The addition of the independent hand brakes assists the user in making tighter turns, including stationary pivots. The safety benefit of the freewheel drive system is that the handles are not driven by the wheels, preventing the handles from striking the user while the chair is in motion.

Both drive wheels were mounted on a solid axle, for which a length of 3/8″ diameter threaded rod was used. Flanged ball bearings were used at the ends of the 1.25″ steel tube axle housing, with a non-flanged ball bearing mounted on the center of the axle. The two cranks were mounted in the same way, inside a separate length of 1.25″ steel tubing, which was welded to the frame during assembly.

The brake system utilized caliper brakes and pads, controlled by cables which were run from the calipers, up through the handles, and to lever controls mounted on the handgrips. The brakes, again, provide independent control of the left and right wheels. This is useful not only for stopping the chair, but also for controlling tight turns.

This design turned out to be very effective. The seat is in a comfortable position and angle. The range of motion and force required to drive the chair are reasonable. The propulsion, steering, and braking systems are intuitive and easy to use. The drive handles can be moved out of the way to allow the user to transfer into and out of the chair. See Figure 20.43.

Several aspects of the current design caused problems with performance. The right-side freewheel hub needed to be mounted in the reverse direction for which it was intended. A standard freewheel hub is one-directional, and in order to provide torque to the right wheel, the right hub needed to be turned around; a washer was tightened against the hub in order to allow the torque to be transmitted in the opposite direction. However, because of this improvisation, the right wheel tends to slip while being driven. The braking system was never completed; more planning was required to allow the brake cables to be run from the calipers and up the handles to the levers. The seat turned out to be too high off the ground, which resulted in some rollovers when traversing an incline at a non-perpendicular angle. The seat height can be lowered and the base widened, to provide more stability to the chair when on unlevel ground. The current single-speed drive system can be replaced by a multi-speed cassette and derailleur, giving the user a wider range of speeds. In addition, reverse drive capability would be a useful add-on, to allow the user to back out of tight spaces.

The overall time investment for this design, from concept to prototype assembly, was approximately 3 months, and the overall cost was approximately $465 plus labor provided by the machine shop.

The cost of the parts and materials is estimated to be $465.

Fig. 20.43. Off Road Manual Wheelchair Prototype.

MANUAL OFF-ROAD WHEELCHAIR

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INTRODUCTION

Our team mission was to design and construct an off-road wheelchair to be used by a person with disabilities with strong upper body muscles to be able to propel the vehicle. Because we anticipate that the wheelchair will be used by an active person, our group also sought to design the vehicle to operate in a sandy environment so that they may travel without repercussion at the beach. Users would normally go through a strenuous process in order to switch between wheelchairs. The last requirement that our team planned to accomplish is to design the wheelchair to be modular in nature. This would allow for the user to board our wheelchair via a ramp and would eliminate the step of switching wheelchairs all together. Currently, our prototype wheelchair meets and surpasses all of the above expectations and requirements.

SUMMARY OF IMPACT

Manual wheelchair users have stronger upper body muscles which allow them to use manual wheelchairs with ease. This means that they will likely be more active and thus more likely to be outdoors. Because this is such a wide topic with various solutions, we had to narrow our focus on what we wanted our design to actually do. So, we decided that the vehicle should be modular and allow the user to drive their wheelchair up a ramp onto our unit in order to remove the inconvenience of switching wheelchairs. The vehicle aims to provide versatility by functioning on the beach as well as on a sidewalk.

TECHNICAL DESCRIPTION

The off-road wheelchair design is actually a modular attachment to a standard wheel chair which allows the user to mount and dismount via a ramp in order to travel on difficult terrain such as dirt and sand. The design of this wheelchair allows for the user to propel the vehicle using two independent levers. Using just one lever, the user can turn in the opposite direction which allows for easy steering. The rider's wheelchair is secured via a ratcheting tie-down which allows for quick maneuvering with minimal inconvenience to the rider.

The core requirement of our design is that it be modular in nature to give the user more freedom and peace of mind while pursuing recreational activities on the beach. Its unique design allowed us to use generic manufactured parts thus allowing for a simple and quick construction and also easier maintenance. The selection of quality components enables the unit to resist corrosion better, live longer, and carry a heavier load.

The construction of our prototype was not as fruitful as we had hoped. Our planned design changed mid-construction of our project which meant that some of our requirements might have to be changed. Our design turned out to be too tall and shifted the center of gravity of the object higher which means it has a higher chance of tipping over when turning. During the welding process, we welded the steel tubing to the platform and the steel tubing to the bike frames. This caused the wheelchair to become wobbly and slightly unbalanced, but still operational. The tires are still too thin to operate efficiently in a sandy environment. Protective shielding has not been installed to protect the gears from the sand and this will accelerate corrosion to the product. Because of its bulky size, it cannot navigate well in cluttered environments. Because this is a prototype, our group focused on functionality and we did not design with aesthetics in mind.

Having produced a functional prototype, it can be considered at least somewhat effective solely in this regard. However, it additionally provides a test platform from which to experimentally evaluate the validity of the concept and thereby suggest improvements. This is a full-scale functional prototype rather than a scale model and as such provides full-scale functionality. While this first attempt is somewhat crude, it admirably embodies the design concept especially when taking into consideration the resources available for its construction. Moreover, the utilization of pre-manufactured systems (the bicycle parts) eliminates some uncertainly about the reliability of the drive system by relying on a proven design.

Our prototype also is quite effective in fulfilling our initial goals. From the drawing board to the finished product, we have remained quite true to what we initially sought to build. To have gone from design to prototype implementation without the need for radical redesign is both uncommon and cost-effective. We consider this to be a significant success and therefore believe our prototype to have effectively met our objectives.

There are many factors in determining the costs for our project and they vary by material choice and design requirements. We had chosen two Wal-Mart bikes for $271.08 which could have been reduced if the bikes were on sale or by picking different bikes that fulfilled our needs. The bar stock, tubing, and threaded rods we ordered from McMaster-Carr were necessary and the cost could have been lowered by downgrading the material quality. However, downgrading material quality would perhaps decrease corrosion resistance thereby reducing the life of the wheelchair. The items ordered at Harbor Freight could have easily been reduced by selecting a smaller model for the castor and the wagon, but the nut and bolt assortment was necessary for construction. We were lucky that our finishing and welding services were free, but normally they would not be and that would therefore raise the price of the product. Overall, the total price with tax came out to $622.18, which is pretty good considering we tried to keep it under $800.

The improvements that can be made to this prototype fall into two categories: design and construction. From a design standpoint, it may be necessary to lower the center of gravity as well as to provide some greater consideration for a method of securing a wheelchair to this modular system. The implementation of brakes would also be necessary for anything other than a prototype test bed. There is no internal braking ability inherent to our drive system and a safely functioning design would require some form of auxiliary friction brakes.

From a construction standpoint, this entire prototype would have to be rethought from the perspective of larger scale manufacturing. Possible considerations include the consolidation of assemblies in order to reduce parts and the use of alternative materials in order to reduce this prototype's somewhat substantial weight. However, this prototype is many iterations away from being a marketable product and therefore any changes made may bring to light future improvements and changes that are not yet apparent at the present.

The cost of the parts and materials is estimated to be $625.

OFF-ROAD MANUAL WHEELCHAIR

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INTRODUCTION

The purpose of this project is to design an affordable and manageable off road wheelchair. This wheelchair is designed to take individuals to places a regular wheelchair cannot. What motivated our group to move toward this goal is the fact that most of the wheelchairs out in the market have mobility constraints and are expensive. The designed wheelchair is capable of taking anybody from point A to point B with a strong gear mechanism that was designed to make the ride easier. It is made of light and strong materials capable of supporting more than 300 pounds.

SUMMARY OF IMPACT

Market research for manual all terrain wheelchair products revealed an opening for items, which can increase an ability of a wheelchair to navigate over unpaved terrain. Standard manual wheelchairs typically do not have the stability or traction to travel on rough terrain. Our aim in this project is to create a manual wheelchair that maintains functionality while traveling over almost any terrain. This design aims to capture part of the market based in its unique characteristics; a good product for an affordable price.

TECHNICAL DESCRIPTION

Most manual wheelchairs have thin drive wheels in the rear with very small pivotal wheels in the front to provide stability. These features, as well as the lack of suspension, create a rough ride while traveling an unpaved path.

For this project, first we broke down the components of a wheelchair to determine which ones we need and its reasons: toe guard for foot safety, adjustable backrest for prolonged user and relaxation, rear and front support wheel for slopes and hills, and washable and removable seat for hygiene. Next, we considered these following six external specification requirements: force applied by the user, travel time of the wheelchair, ability to follow a defined path, range of travel, user comfort, and safety.

The prototype design for the all-terrain wheelchair consists of a major subsystem and few additional parts. The power system consisting of two sets of gears, and pedals which provide the mechanical advantage necessary for a user to move about comfortably in the wheelchair on any terrain. The transmission system also consists of two brake linkages mounted on rims, which assist in stopping and also stabilizing the wheelchair during vertical descent and ascent. The oversized wheels create more surface area for traction, and more accurate mobility. In order to measure the effectiveness of our Off-Road Wheelchair prototype the categories that we might look at are accessibility, weight limitations, mobility, safety, ergonomics, compact ability, reliability and cost.

The cost of the parts and materials is difficult to estimate at this time.

CHAPTER 21
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MOTORIZED STORAGE SHELF

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INTRODUCTION

The objective of this project was to develop a motorized storage shelf unit which would give the clients, a couple using wheelchairs, a functional and accessible storage space for groceries and kitchen items. The clients, who have cerebral palsy and multiple sclerosis, have limited reach to their existing kitchen cabinets above the counters. A mobile and standalone unit was developed to provide them with a functional and accessible storage space. The unit consists of a motorized four shelf assembly that moves within a cabinet. An electric hoist, with step motor power control, was used to allow the shelf assembly to move to the desired height during loading and unloading. Figure 21.1 shows a 3D computer model of the unit, which is depicted in Figure 21.2. The unit is easily accessible to a wheelchair user and is easily operated using "push button" automation.

SUMMARY OF IMPACT

The clients, a couple using wheelchairs and who have cerebral palsy and multiple sclerosis, cannot reach their existing kitchen cabinets above the counters to store items. Jim has limited use of his hands while Rebecca has total use of both hands. However, reaching kitchen cabinets was not possible for them since they are in wheelchairs. Their desire was to be able to independently store groceries, kitchenware, spices, and other items. A mobile and standalone unit was designed and constructed to give them accessible storage space for groceries and similar kitchen items. The unit was placed away from the existing cabinets, but close to the kitchen. This design allows full use of the existing counter space and would not decrease the resale value of the clients' condominium by modifying the existing cabinets. The developed unit employs simple "push button" automation and allows free accessibility. The clients were satisfied with the cabinet as it allowed them to independently, easily and effortlessly store and unload items from it. Also, current commercially available devices were costly.

Fig. 21.1. Computer model of the unit.

TECHNICAL DESCRIPTION

The three most important requirements for the developed unit were that it be safe, functional, and easy to use. Likewise, the device would restore functionality to the existing living space while not decreasing the condo's resale value (by modifying existing cabinets). In the event the clients should move, the device could be easily relocated to a new

Fig. 21.2. The final prototype.

home. The existing kitchen cabinets were small and ceiling mounted, severely limiting design options. The best option was thus to design a unit that is mobile and standalone, away from the existing cabinets, but close to the kitchen.

Since the clients found it hard to reach usable areas in their kitchen, a design had to be considered having complete accessibility with minimal effort. Additionally, it would be able to store items of heavy load capacity such as dinnerware or pots and pans. The standalone design would allow the client to store items at wheelchair height and then allow those items to be moved to another position in order to maximize floor-to-ceiling usage. The space occupied by such a device would have to allow for effective, but uninhibited accessibility. The clients had such a space, which was conveniently located in their living room, adjacent to their kitchen and was roughly 32 inches wide, 24 inches deep, and 84 inches high. Equally important, the space had a dedicated electrical outlet that was currently not being used. This was utilized for the power source of the motorized shelf system.

To accommodate the clients' needs, two concepts were considered for the project: a rotating carousel shelf system, and a winch-assisted drop-down shelf system, The first concept considered was similar to a storage system that is currently on the market for disabled persons, the AutoPantry. The design involves a powered carousel assembly of shelves that rotate around a track-type system. This design is largely considered for use in available pantry spaces and large cabinets. The device would require a system of bins or shelves attached to a complex assembly of sprockets or idlers powered by a motor-driven chain or belt. The chain would carry the shelves in a rotating carousel fashion from the front of the cabinet to the back as needed. An electric motor would be mounted in the base of the cabinet to power the carousel. The rotating carousel system would allow ease of operation with minimal effort. In addition, it would be able to carry a large load capacity. However, because the system would have a multiple chain or belt drive around a system of sprockets, it would have less reliability. In order to ensure clearance for free rotation, the bins or shelves would have to be of smaller size. Also, large unsteady objects might fall off the shelf causing a potential jam.

Since the clients desire maximum use of the space available, the second concept employed a "box within a box". The motorized winch, mounted on top of the cabinet, would pull the boxed storage shelves up or down as needed in order to store items. The design would give the clients the most amount of usable shelf space. Since it is a relatively simple design, it requires the least amount of components at lower cost. Also, the client would be able to actuate the shelf to the height of their wheelchair with the push of a button. The safety concerns here would be failure of the wired cable and the clients' reach restrictions. In order to counter the reach restrictions and maximize efficient use of each shelf, an array of pull-out baskets or bins would be mounted on most shelves.

A "House of Quality" assessment was used to analyze the two designs with consideration for the needs of the client. The second design concept, the winch-assisted drop down shelf, was found to be a better design. Design considerations were safety, functionality, and ease of use. Using a linear actuator instead of a winch was also considered. However, the cost and the positioning of such a component eliminated its choice.

Material selection was based on accessibility and aesthetic qualities that would exist with current living arrangements. The unit was constructed mostly of ¾″ cabinet grade plywood which is the standard wood grade for cabinets. The inner movable shelf consisted of ¾′ cabinet grade birch plywood for the outer shell, with ½″ plywood shelves. This inner shelf was reinforced by 1/8″ thick 2″x2″ steel angles (1020HR) at each corner and 1/8″ thick steel side braces for structure strength, welded midrange onto the corresponding top and bottom angles. The top beam that connects the shelf unit to the hoist was a ¼″ thick, 3″ x 1″ steel channel for durable structure strength. The entire cabinet stands on minimally 5″ rolling casters. The cabinet stands seven feet tall, thirty one inches wide and twenty four and half inches deep. The box inside is forty inches tall, twenty nine inches wide and twenty one inches deep.

The hoist motor is controlled by a set of electronics to make operation as easy as possible for the client. A 24 volt power supply powered a PLC (programmable logic controller). A CLICK micro PLC by Koyo was specifically used. It has 8 digital inputs and 6 digital output channels. A photoelectric eye was also mounted at the back of the cabinet and was used to control the system along with the PLC. Reflectors are mounted in the back of each shelf. The programming was done as ladder logic. The PLC inputs were simple pushbutton switches controlled by the user. The outputs were two double pole relays. The motor wiring was routed to these relays to allow the PLC to turn the motor on and off. The wiring schematic is illustrated in Figure 21.3.

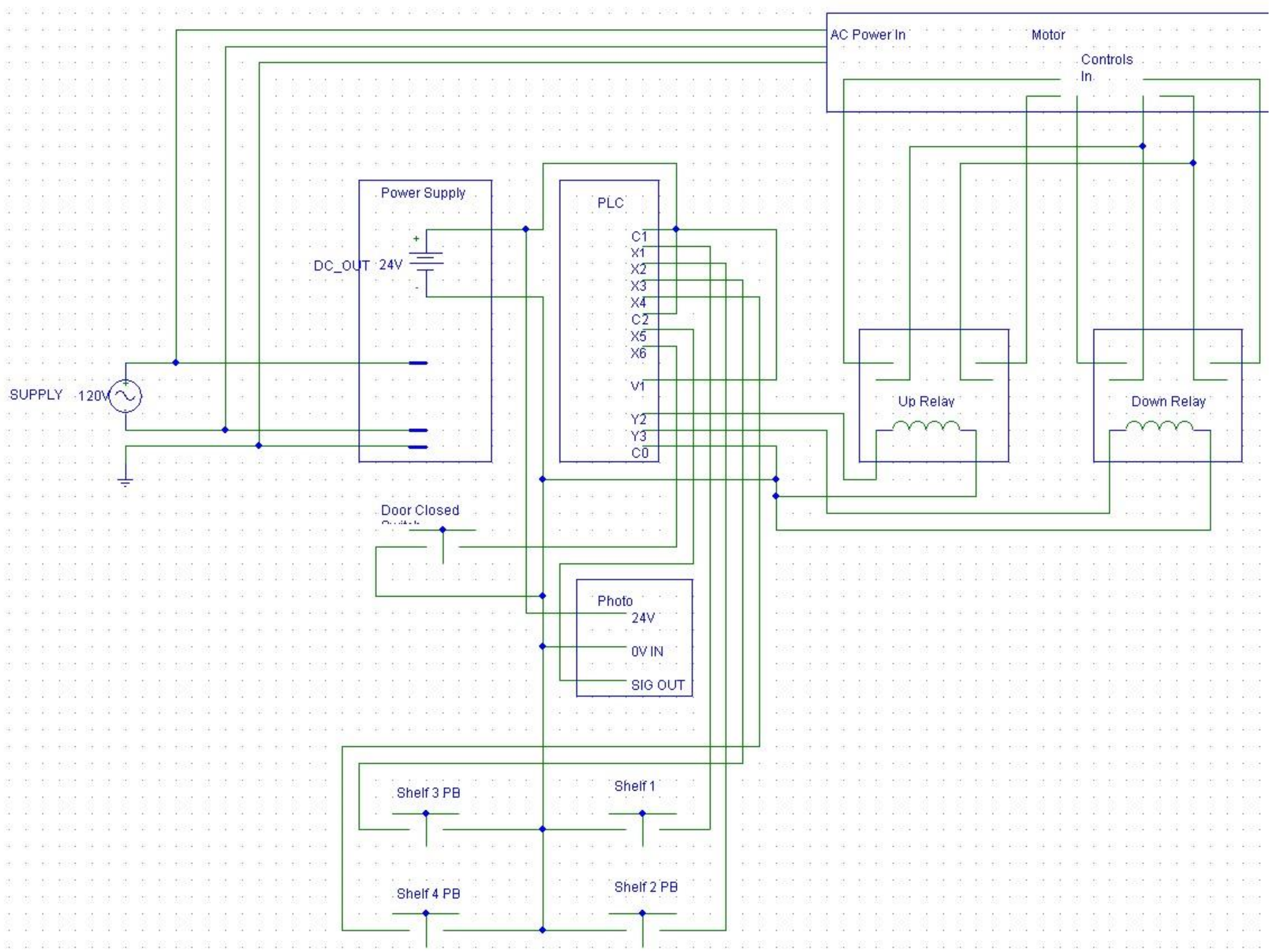

Fig. 21. 3. Wiring schematic to allow the PLC to turn the motor on and off.

The programming works as follows. The user opens the far door to deactivate a door switch. This allows them to select a shelf they want using the side pushbuttons. The PLC read which shelf button was pressed, turns on the motor to move the shelf. The photoelectric eye reads a set of reflectors behind the shelf to count which shelf it is passing. When the eye senses the proper shelf, it shuts off the relay, stopping the motor. The user can hit any button at any time to move to the next appropriate shelf. When the user is finished, they shut the cabinet doors. This closes the door switch, and the PLC drops the shelf so it is resting at the bottom of the cabinet. The photoelectric eye reads when the shelf has reached the bottom, and the PLC shuts off the relays and stops the motor. The purpose of having the shelf at the bottom of the cabinet is two-fold. The weight is off of the hoist cable when the shelf is not in use, so it's easier on the cable. Also, if there is a power outage, the shelf is at the bottom of the cabinet. By opening the bottom doors, the user can still have access to the shelves. Another safety measure was incorporated in that the cabinet cannot be actuated with the right side door open, preventing fingers near the push buttons from entering the moving shelf area.

Structural analysis was performed on each major component of the assembled design, and all factors of safety were greater than 2. The deflection of the top plate (steel channel) of the inner shelf assembly as it holds an estimated maximum load of 550 pounds as shown in Figure 21.4 was calculated as 0.009 inches.

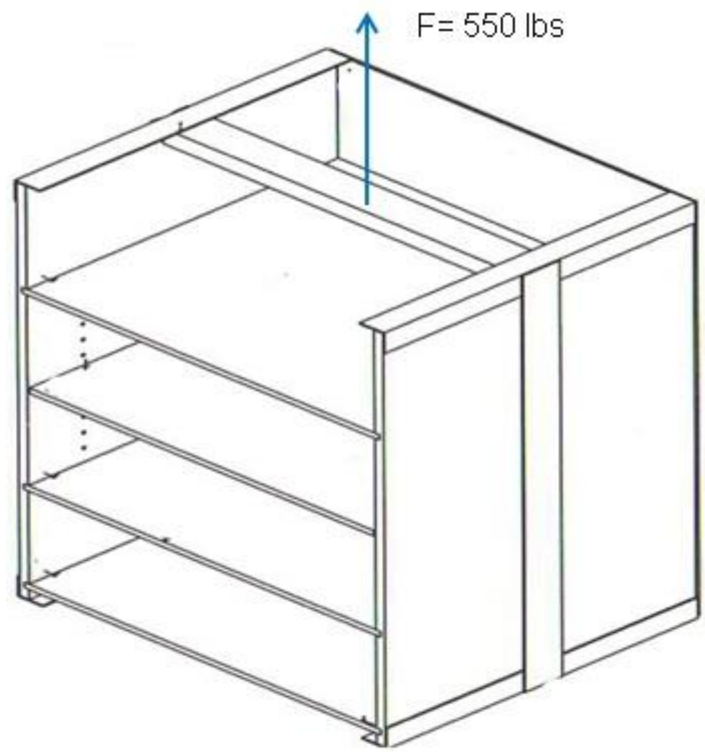

Fig. 21.4. Box top beam deflection analysis.

The inside box is carried by a ten thousand pound capacity cargo D-ring bolted to the top plate of the inner shelf assembly by two, two and half inches grade nine bolts. The box hangs from the top by a hoist is rated at 1-1/8 HP and capable of lifting 880 lbs. The inside box is guided by aluminum tracks to give it more stability and eliminate rocking motion. The inside box is divided using four equally spaced shelves, 9.5″ apart. The shelves slide out with a lip in the front and the back preventing items from sliding while moving. The upper doors of the cabinet are 50.5″ tall and 14 ¼ inches wide. The bottom doors of the cabinet are 26.5″ tall and as wide as the top doors. The total weight of the cabinet is approximately 325 lbs. All switches are orderly mounted to the side of the cabinet. Insulation was placed around the hoist compartment to reduce the noise.

The total cost of the project was about $700.00. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address:

http://www.eng.utoledo.edu/mime/design/clinics/2010/Fall/2010-03-01/

A video of the final product working is posted at the following URL address:

http://www.youtube.com/watch?v=xfbDRf8RJZY&feature=plcp

Figure 21.5. depicts different pictures showing how a wheelchair user can use this unit independently and effortlessly.

Fig. 21.5. This figure depicts four pictures showing how the unit can be operated by a wheelchair user.

Fig. 21.5. Continued.

ASSISTIVE DEVICE FOR GOLF PRACTICE

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INTRODUCTION

An adolescent in a wheelchair is being trained to properly swing a golf club in order to effectively drive a golf ball. The device he currently uses is inadequate to train him to independently play a game of golf. The current training device in use is known as the Explanar, and is designed so that a person may stand inside to practice his or her golf swing as shown in Figure 21.6. A hoop surrounds the golfer and a "Plane Fin" is located at the top of the hoop, and "is a diagnostic tool. Rather than being supported and adjusted by a post in the back as seen in Figure 21.6, another design, shown in Figure 21.7, is supported and adjusted by two hydraulic cylinders on either side of the hoop. The Explanar is intended to remain in a single location during use, and is not designed to be used with actual golf clubs. Instead, it uses a 'Power-Roller". This leaves novice golfers finding it difficult to recall their swing after leaving the practice area to play on the golf course. This project is intended to address the deficiencies with the "Explanar" by implementing a new design that is tailored to the "client" abilities as well as the needs of others with physical impairments. This particular device should be based on the principles of Ben Hoga's golf swing theory requiring the club not to break an imaginary plane of glass running from the ball through the shoulders. The final design consists of two concentric circles made of steel round stock. The circles hinge at their midpoint to allow the device to fold in half. The circles are held parallel using bolts that thread through the hinges as well as several spokes welded to the members to create the desired swing plane. Two A-frames support systems hold the plane at it central axis and allows it to pivot to various angles. The plane is locked in its desired position using a crown bolt in each hinge to prevent rotation. The A-frame includes a comb-like cross member that is notched at discrete locations to allow the device to adjust to an individual's height. Finally, pneumatic wheels suitable for use on the golf course are mounted to each leg of the A-frame to allow the device to be easily transported. Figure 21.8 shows a model of the new unit, and Figures 21.9 and 21.10 depict two pictures of the completed prototype.

Fig. 21.6. Explanar Junior model.

Fig. 21.7. Explanar teaching version.

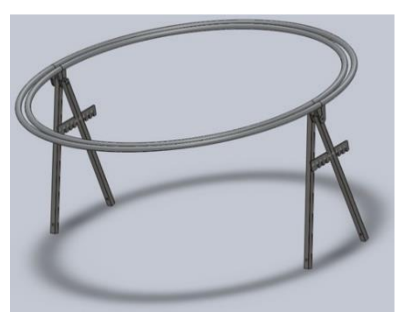

Fig. 21.8. New prototype.

SUMMARY OF IMPACT

Currently, one individual in a wheelchair is being trained to golf from a seated position. The golf course where he trains has a device that is not suitable for use by a person in a wheelchair and is not intended to be used with an actual golf club, but rather a supplied rolling club. This device is also not designed for easy mobility, and is generally only moved for storage and for placement in a permanent setting. The unit that was developed would allow this person to train from his wheelchair using his personal golf equipment. It is also portable to enable him to train from various locations on the golf course. This design not only allows a person in a wheelchair to use it, as was requested, but also allows people of multiple physical abilities to practice their golf swing. It pivots to accommodate various ranges of motion, adjusts to various individual's heights, and can be used on the course itself. This design proves its usefulness as well as its uniqueness as an active teaching tool on the golf course for anyone looking to improve their golf swing.

TECHNICAL DESCRIPTION

A basic prototype was first built using plywood and PVC pipe. This allowed the finalization of the design concept that is shown in Figure 21.8. Two A-frames were employed to support the unit at four points. A comb-like cross member is attached to one of the legs of the A-frame on both sides of the device and has a series of notches that fit over a pin on the other leg, thus allowing the device to be height adjustable at discrete increments. This allows a person in a wheelchair or a person with use of their legs to have the device set to accommodate their individual heights. The hoop angle adjustment accommodates the range of motion of various individuals. The swing plane was created by using two concentric circular rings made from galvanized steel. Galvanized steel was selected for its malleability and resistance to rust. These two rings are hinged at the midpoint so the device can fold in half horizontally and pivot about a central axis. The rings are held together using a series of spokes, much like a bicycle rim, so that they move in parallel, which allows to maintain the proper swing plane after the device had been set up. To prevent the swing plane from rotating, a crown bolt was used in each hinge which allows a user to adjust and lock the plane in its proper orientation before using the device. A nut with two bars welded to the sides was attached to the bolt and acts as a T-handle knob allowing the user to apply enough torsional force to pinch the legs and hinges of the device together and secure the hoops in place. The unit is mounted on pneumatic wheels suitable for use on a golf course. While the device weight was about 100 pounds, the use of pneumatic wheels made the unit appears much lighter when moving it. The wheels also serve as a damper for the forces on the hoop.

Structural analysis was conducted on the A-frame comb-like cross member to determine its length, cross sectional area, height of central axis from the ground, and width of the A-frame base in its various positions. Impact analysis was also performed to determine the maximum impact force the unit could experience from a person who unintentionally struck it while trying to hit the ball. For an impact time of 500 microseconds, and using club head mass and swinging speed of different golf clubs, ranging from a driver to a nine iron, the largest impact force the unit would be subjected to was calculated at 4,800 lbf.

Fig. 21.9. Final prototype.

Fig. 21.10. Final prototype.

ATHLETIC THROWING CHAIR

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INTRODUCTION

The client, Zena, throws a discus and club in the Paralympics. The Paralympics' rules state that an athlete can have a 29″ throwing chair, measured from the top of the seat to the ground. Zena throws from a 22″ tall standard electric wheelchair. She cannot lift herself out of her chair into a 29″ chair because she has complications from Polio. The purpose of this project is to develop a throwing chair that can raise her from 22″ at the loading height to a throwing height of 29″. Such a chair does not exist in the market. The unit that was developed includes four (4) telescoping legs connected to an upper and lower frame made from low carbon steel. The upper frame was connected to a rising seat assembly. A hydraulic scissor jack provides a 7″ stroke to bring Zena from loading to throwing height. The lifting mechanism is operated manually by the user. Figures 21.11 and 21.12 show the client using the chair in the lowered position at 22″ and in the raised position at 29″, respectively

SUMMARY OF IMPACT

Zena Cole, a Para Olympian, is unable to lift herself out of her wheelchair into a higher one. Therefore, she is not able to effectively compete in the discus and club throwing events. The unit that was developed allows her to raise herself from a loading height of 22″ to a throwing height of 29″. This will allow her to compete to her highest potential at the Paralympics. Zena was very pleased with the throwing chair, and found it very effective and easy to use.

Fig. 21.11. Seat in the loading lowered position.
position.

Fig. 21.12. Seat in the throwing raised

TECHNICAL DESCRIPTION

The design criteria was to develop a throwing chair that would allow the client to transfer into it safely at 22 inches and to raise her 7 inches to a throwing height as allowed by the Paralympics Rules. Some other Paralympics Rules include that the throwing chair must have a seat belt, that the chair must have the ability to be strapped down to the throwing circle using tie-downs, and the chair once raised must be locked into place to not give an unfair competitive advantage. The client also included other requirements as that the chair must allow her to transfer into it from its left side, and that there must not be any parts of the chair that will obstruct the throwing motion.

The chair design that was developed uses a hydraulic jack along with telescoping legs to raise and lower the seat. The chair includes an upper moving frame and a lower stationary one. The seat is attached to the upper frame using the telescoping legs that support the weight. The jack is attached to the bottom of the seat and to the bottom frame. A hand lever is used by the user to raise and lower the seat. Mechanical stops were incorporated in the telescoping legs to precisely control the height. Safety pins, 0.5″ in diameter, are engaged through the stops to keep the chair from falling in case of hydraulic failure. The throwing chair has two wheels mounted at the bottom frame so that the chair can be rolled around while it is tipped over. The chair allows Zena to transfer to it from its left side, and includes an arm rest on its right side. The chair does not have a backrest. As the client throws, she is supported by the side arm rest. The pump of the hydraulic lift is able to lift a load of 300 lbs. at least 7 inches. The frames were made of SAE 1020 (low carbon steel) 2.5″ OD square tubing and 0.25″ thick. The telescoping legs were made from SAE 1020 tubing. They included 2″ ID, 0.25″ thick tubing, and 1.5″ OD, 0.5″ thick tubing. 2″ OD bushings made of lubricated bronze were also used in the system. A standard car seat belt and a seat cover made out of Styrofoam were used.

During construction, the top and bottom frame were put together separately. The alignment of the telescoping tubes was very critical for a perfect operation. The mechanical stops were welded to the top frame and the bushings set in place on the tubes. Figure 21.13 shows a picture of the chair during the assembly process. During the final assembly, Rustoleum spray paint was used to paint the chair. The seat and leg rest were made using Styrofoam packaged in vinyl. They were attached to the chair by using Velcro so that the seat and leg rest could be taken off easily. The seat belt was attached at the arm rest using 2″ bolts. Eyebolts were then connected to the upper frame. A picture of the final assembled chair is shown in Figure 21.14.

Structural analysis was conducted on the chair and its components, and the unit was found to be safe with a large factor of safety. The total cost of materials for the unit was $500. The prototype was assembled with the help of friends and family of the design team.

Fig. 21.13. Chair during assembly.

Fig. 21.14. Final assembled chair.

GURNEY MATTRESS REDESIGN

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INTRODUCTION

Trauma to the spinal cord results in the inability of the patient to move and feel below the neck. When transporting these individuals on a gurney to perform routine tests, they are prone to excessive pressures over long periods of time that may result in the formation of pressure ulcers. Pressure ulcer formation is most significant near the boney prominences at the sacral or tailbone region when the patient is lying down supine. During many routine tests, a patient is transported while lying on the gurney with an inclined back rest, which increases the pressure in the sacrum region. The current gurney mattress uses two layers of different density foam to disperse the pressure. However, it is ineffective at distributing pressure around the head, sacrum, and heel region. Unpublished data show that when using the current gurney mattress, mean sacral pressure increased with back rest inclination from 65 mm Hg at 0^{o} to 139 mm Hg at a 75^{o}. Experimental studies performed on dogs show that a constant pressure of 60 mm Hg for one hour will cause irreversible tissue damage. As the inclination of the back rest increases, pressure over the sacrum increases and if the patient is left in this position for any extended period of time they are at high risk for pressure ulcer formation. The objective of this project is to develop a gurney mattress that will increase pressure dispersion and decrease sacral pressure in order to reduce the risk of pressure ulcer formation. In order to achieve this objective, the new mattress must exhibit a reduced pressure while the gurney is inclined to a maximum of 75^{o}. The new mattress must also still fit in the standard hypoallergenic cover that is used in hospitals. Two gurney mattress prototypes were developed to improve dispersion and reduce pressure on the sacral region of the body. The bottom layer of the mattresses was made of firm foam. The top layer of the mattresses was made of two softer foams. In one prototype, the top layer of the mattress is constructed using soft foam that runs along the length of the unit, and surrounded on both longitudinal sides with firmer foam. In the second prototype, wide pieces of foam were sequentially placed to form the top layer of the mattress. Figures 21.15 and 21.16 show pictures of these two prototypes, respectively.

Fig. 21.15. Prototype 1.

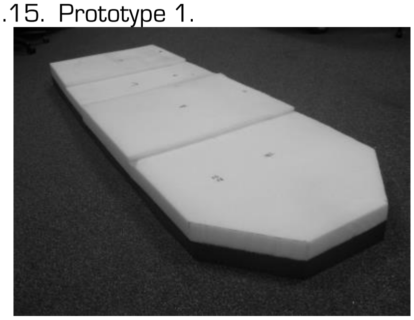

Fig. 21.16. Prototype 2.

SUMMARY OF IMPACT

The financial burden to treat pressure ulcers is high. The cost to heal a single complex full-thickness pressure ulcer has been estimated to be $70,000 and the total economic burden of treating all pressure ulcers was estimated to be as high as $1.335 billion per year. These costs not only load society with an enormous financial burden, but the patient must undergo a series of treatments that may last for months which will remove them from productive activities. The prototypes were tested and were found to reduce the maximum pressure by at least

25% from that found in the current mattress while the gurney backrest is at its maximum elevation of 75 degrees. This will reduce the probability of the users developing debilitating bed sores.

TECHNICAL DESCRIPTION

Existing gurney mattresses used by hospitals use two layers of different density foam to disperse and reduce the pressure. The top layer is made of softer foam than the bottom layer. The new design explores using different foams of different geometrical configurations for the top layer. In order to determine which foam to use for the new mattress, six foams of different densities and materials were obtained from BuyFoam.com, a wholesaler to the Upholstery and Mattress trades. These foams are the XL-18#, XL-28#, XL-38#, and XL-48# foams which are made from open cell polyurethane, the HR-33# made of open cell polyether, and the black foam made of Open Cell Ester. The material properties of each of these foams were determined experimentally by carrying a uniaxial compression test on 3″ thick by 3″ diameter and 3″ thick by 6″ diameter cylindrical specimens. Results have shown that the XL-18# is the softest and the black foam is the firmest. Results also show that the HR-33# foam exhibits different characteristics than the other five foams whose stress-strain curves have initial elastic portion followed by a nearly flat portion (perfect plastic) followed by a non-linear plastic region. The stress-strain curve of the HR-33# does not have a flat portion and displays initial suppleness at low stresses and good support at greater stresses. It was then decided to use the XL-18# and the HR-33# foams to construct the top layer of the mattress, and to use the black foam for the bottom base layer. Two designs, longitudinal and transverse geometrical configurations, were considered for the top layer of the mattress as shown in figures 1 and 2. In the first one, a longitudinal strip of soft XL-18# foam was used to absorb the majority of the pressure and disperse it to the other foams. On either side of this foam is the HR-33# foam that is used to provide support to the patient while still being able to prevent pressure buildup. In the second design, wide pieces of XL-18# and HR-33# foams were sequentially placed to form the top layer of the mattress. The XL-18# foam was placed in the areas of the sacrum and the heels, while the HR-33# over the remaining surface. The two new prototypes were constructed and fit in hypoallergenic covers currently used in hospitals. The assembled units were tested with the gurney at various inclinations up to 75°. A Force Sensing Array (FSA) pressure mapping system that shows the amount of pressure between two contacting surfaces was used to measure the pressure between the subject's sacral region and the mattress. The system includes a pressure mapping mat that is placed in between the subject and the board and is interfaced with a computer that has supporting software for the mat. Pressure maps using the current mattress available in hospitals and the new longitudinal and transverse designs are shown in Figures 21.17.a, b and c, respectively. Both new units show a pressure reduction from the current design. At the maximum gurney elevation of 75 °, a maximum pressure of 178 mm Hg was recorded at the sacrum with the current unit, and maximum pressure of 118.5 mm Hg and 129.3 mm HG were recorded when the new longitudinal and transverse designs were used, respectively. The mattresses were also tested for sacral interface pressures at other backrest elevations and a reduction in maximum pressure was observed at all angles with the new designs. The total cost of the material was $325.

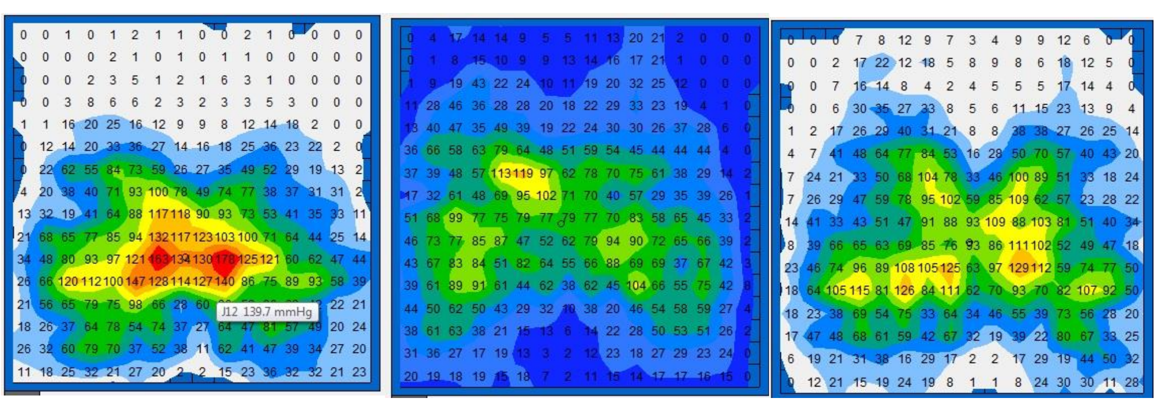

Fig. 21.17. a) Pressure map using the mattress currently used by hospitals; b) Pressure map using prototype 1; c) Pressure map using prototype 2.

DEVICE FOR REHABILITATION OF SHOULDER INJURIES

Student Designers: Anthony Hamberg, John Galloway, William Bierie, Mechanical Engineering Students
Client Coordinator: KC Ruddy, Physical Therapist
Supervising Professor: Dr. Mohamed Samir Hefzy and Dr. Mehdi Pourazady
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INTRODUCTION

The objective of this project is to develop a device that will aid in the physical therapy of patients that have undergone shoulder surgery. The client is a physical therapist that has been using a simple broomstick and understands the need to develop a new device that will better fit the patient. The problem with the broomstick is that it only allows for an overhand or underhand grip, which is difficult for the patient because the grip positions pinch the repaired tendons and do not allow for the patient's limited range of shoulder motion. A device was designed that incorporates freely rotating handles which can be adjusted and locked into place to suit different patient's ranges of motion. Two prototypes, shown in Figures 21.18 and 21.19, respectively, were developed. They were made of aluminum to be light enough to not strain the patient's healing shoulders, but strong enough to support added weight. The length of each prototype was adjustable between 16 inches to 26 inches to accommodate patients with different shoulder widths.

SUMMARY OF IMPACT

Shoulder surgery is very common, and it ranges from minimally invasive outpatient surgery to complete shoulder replacement. More than 5 million people visited the doctor because of rotator cuff problems between 1998 and 2004. It is also estimated that about 53,000 Americans undergo complete shoulder replacement every year. These statistics are only expected to rise as a result of the increasing population of seniors in the US. Since most injuries are a result of joint deterioration by arthritis and osteoporosis, a majority of shoulder surgery patients are in the upper age bracket. Shoulder recovery also takes an extensive amount of time, with 75-80% of one's strength returning in 6-7 months for some and up to a year for others. Much of the recovery is done solely by the patient, but in the earlier stages the supervision of a physical therapist is required to assist shoulder movement and make sure it does not become over-strained.

Early in the rehab process, a device is often used by the patient in order to help work the operated shoulder using the strength of the good shoulder. Today, the most commonly used device is a simple straight stick that is made of wood or plastic, but this causes problems for the patient. The only possible grips on the stick are an overhand or underhand grip, which both have their problems. The overhand grip places the shoulder in a poor biomechanical position and often pinches the repaired tendons, while the underhand grip is difficult for a patient because the range of motion after the operation is very limited. It is crucial that the repaired joint does not suffer any further injuries for the sake of healing time and further complications. The developed prototypes allow for an increased range of grip positions for increased patient comfort and decreased chance of joint damage.

TECHNICAL DESCRIPTION

Design requirements include developing a device that allows for an increased range of grip positions. The device must incorporate several features in order to fit patients of differing size and abilities after surgery. It must be adjustable in length to accommodate patients with differing shoulder widths. Taking into account different ranges of motion, the handles must be able to freely rotate for adjustment and then securely lock into place. Since the patient's shoulder is often very weak after surgery, the device must be as light as possible, while at the same time being strong enough to support added weight. This weight is added to the device as the patient's shoulder begins to regain its strength. This strength can be in the form of wrist and ankle weights that wrap around the device or from a machine such as a pull-down exercise device. For this reason, the device should have an attachment point in the center that can accommodate the machine weights.

This device must not only be designed for the patient, but for the physical therapist as well. With the high number of shoulder surgeries being conducted every year, a physical therapist will often see dozens of patients in a given day. Because of this, the device must be quickly and easily adjustable. Also, the device will be in a hospital setting, so it must be easily wiped down to prevent in the spread of germs from patient to patient. A physical therapist will also have the patient set up their own device, and since a majority of shoulder surgeries are conducted on older men and women, the adjustments must be easy and able to be done with weak hands. The device will most likely be dropped on a regular basis because of the patient's strength, so durability is crucial.

While designing the device, it must also be kept in mind that it will be marketed commercially to physical therapists and individuals everywhere. To help market the device, the material and overall appearance must be aesthetically pleasing. Also, it must be easily manufactured and have a low production cost that allows room for profit and an affordable consumer cost. Keeping all the requirements in mind, the design that best supported the customer requirements was chosen using a house of quality for the material and design.

The design featured two handles in the form of half hoops attached at the end of an adjustable bar. The handles rotate around a hinge located on the outside of the half hoops as shown in Figure 21.18. A slider mechanism, also shown in Figure 21.18, allows changing the length of the device easily. Another prototype, shown in Figure 21.19, was also developed to allow each handle to rotate around its center. This provides the best ergonomically design because all handle rotation is done by the wrist than by the wrist

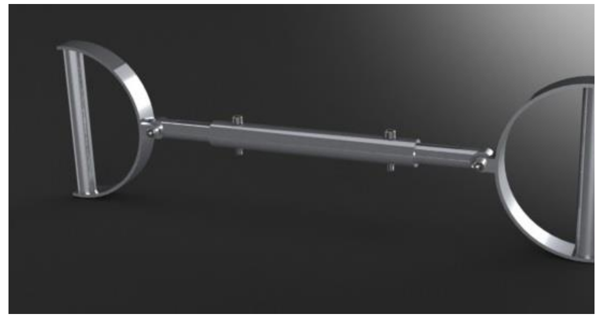

Fig. 21.18. Prototype 1.

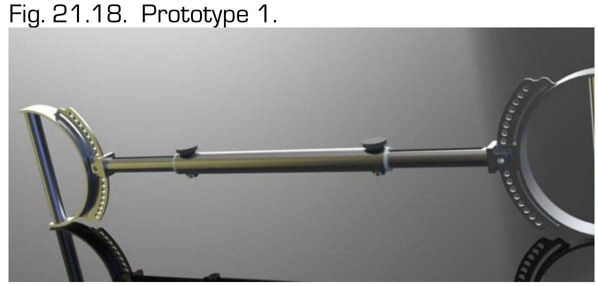

Fig. 21.19. Prototype 2.

and shoulders. However, the second prototype is harder to manufacture.

The middle section of the device was made using aluminum tubing, 1″ outside diameter and 0.87″ inside diameter. In the second prototype, ASTM A574 steel shoulder bolts and 1010 steel pins were used. Structural analysis was conducted using a static load of 40 lbs applied directly to the middle section of the device to simulate the attachment to a weight machine. To simulate an operator pulling the handles apart, a 10 lb. load was used when the handles were analyzed. The units were found to be safe with a minimum factor of safety of 2.1. In both prototypes, the handles rotate independently of each other. Also, the handles can be detached easily using an Allen wrench for a gripping material to be added or replaced as necessary. The total cost to build both prototypes was around $225.

CORRELATING AIR CUSHION'S INTERNAL PRESSURE TO BUTTOCK'S PRESSURE

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INTRODUCTION

Spinal cord injury patients are at risk of developing pressure ulcers because of their inability to know when to adjust position in their wheelchairs. This inability to determine necessary repositioning comes from the lack of sensation in the lower body. Generally, people shift in their chairs to reduce pressure in certain areas of their buttocks or legs. Without the capability of feeling discomfort, the wheelchair-bound patients will sit continuously without realizing that a pressure ulcer is developing. ROHO cushions are used to help preventing the formation of pressure ulcers. A major problem with an air cushion is setting it correctly. Setting an air cushion is done while the user is sitting on it with a goal of submersing the user as much as possible into the cushion. This is achieved by keeping the internal air pressure in the cushion as low as possible without letting the bony prominences touch the base of the cushion. This is challenging. For example, the instruction manual for one of the ROHO cushions (a Roho Incorporated Low Profile® Single Compartment Cushion 16" X 16", 9 X 9 Cells, 2" H), Adjustable Roho indicates that the cushion must be set so that the lowest point on the patient's buttocks is one inch from the wheelchair seat. This is very difficult to achieve as the lowest point on the buttocks is generally not visible when seated normally. Another issue is the usual method of determining the minimum pressure of the air cushion. It is suggested that the user stick two fingers underneath their buttocks and let air out of the cushion until their fingers fit snugly between their buttocks and the wheelchair seat. This is not a very reliable method, especially considering that the patient has no feeling in their buttocks which makes adjustment based upon feeling that much more difficult.

Fig. 21.20. Roho air cushion used in this project.

The purpose of this project is to develop a systematic and reliable method to adjust the internal pressure of a ROHO cushion to reach an optimal value that will minimize the pressure on the buttocks of the cushion user. The closing pressure of arterial capillaries is 32 mmHg or 0.62 psi (1 psi = 51.71 mmHg) which means any pressure higher than this exerted on the capillaries will cause an impediment in the flow. This gives a target for reducing the pressure to as close to 32 mmHg as possible. In this project, a simple air pressure gauge and an electric pump/bleeder valve combination to control the volume of the air in the cushion were used to monitor the internal air pressure. In order to prevent bottoming out of the patient, supplemental foam cushion was used. The effect of supplementing the air cushion by employing varying densities of foam underneath the cushion in further decreasing the pressure on the buttocks of the user was thus investigated. Also, force sensing sensors (FSR) were used to alert the patient when bottoming out has occurred.

SUMMARY OF IMPACT

Air cushions are widely used to decrease the pressure placed on the buttocks of a wheelchair user. However, the method to determine the proper cushion air pressure is not accurate or reliable or reproducible. Users stick two fingers underneath their buttocks and let air out of the cushion until the fingers fit snugly between their buttocks and the wheelchair seat. This is the first study to the best of our knowledge that correlates the cushion internal pressure to the buttocks pressure in an attempt to quantify the optimal cushion air pressure that will produce minimal buttock pressure. It was found that when the internal cushion pressure is set around 0.6 psi, the buttock's pressure reduces to about 32 mm Hg which is the maximum pressure that will not cause flow impediment.

TECHNICAL DESCRIPTION

Several methods are used to minimize the contact surface pressure exhibited at the buttocks of a wheelchair user including using water, gel, foam, memory foam and air cushions. The firmness of the cushion and its comfort level can be adjusted only in water and air cushions. A water cushion could leak and is heavier and stiffer than an air cushion. ROHO air cushions appear to be widely used by wheelchair users to reduce buttock pressure. Accordingly, one of the ROHO cushions was used in this study, namely the Roho Incorporated Low Profile® Single Compartment Cushion 16" X 16", 9 X 9 Cells, 2" H, Adjustable Roho. The design consisted of adding a thin foam cushion underneath the air cushion and coupling that with a pressure monitoring system for the air cushion.

An air pressure gauge was used to monitor the internal air pressure of the air cushion. Through experimentation, the optimal value for internal pressure was determined, requiring the patient to only check that the gauge reading was consistent with the optimal pressure found during testing. An analog pressure gauge was used to allow the user to monitor the pressure of the cushion in real time. An air pump was used to inflate the cushion with the push of a button, and a bleeder was used to allow air out of the cushion. A force sensing array (FSA) pressure mapping system (Vista medical, Canada) that shows the amount of pressure (in mm HG) between two contacting surfaces was used to measure the pressure between the subject's buttocks and the air cushion. The system includes a pressure mapping mat that is placed in between the subject and the air cushion and is interfaced with a computer that has supporting software for the mat.

Figures 21.21 and 21.22 show how the maximum buttock pressure changed while changing the internal pressure of the ROHO cushion when two different members of the team tested the system. Results are shown with and without using a foam supplement to the ROHO cushion. These figures show that the buttocks pressure decreased from a maximum value when the internal cushion pressure was 0 psi to a minimum value when the internal pressure was around 0.5 to 0.8 psi. These figures show that supplementing the air cushion with a foam cushion decreased the buttocks pressure. Similar results were obtained for the other two team members. The average internal air cushion pressure that corresponded to a minimum buttock pressure was 0.62 and 0.63 with and without supplemental foam. The corresponding average minimum buttock pressure was 0.62 psi and 0.72 psi, respectively, which is equivalent to 31.9 mm Hg and 37.2 mmHg, respectively. The total cost for all valves, foam and tubing was $330.

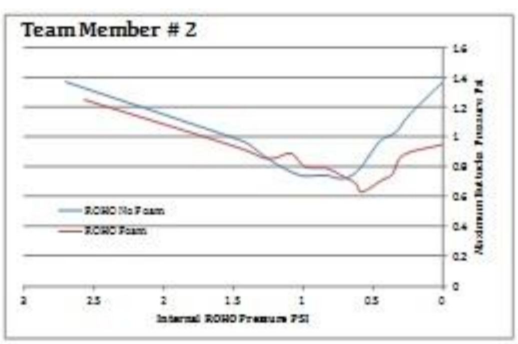

Fig. 21.21. Cushion's internal pressure vs. buttock pressure.

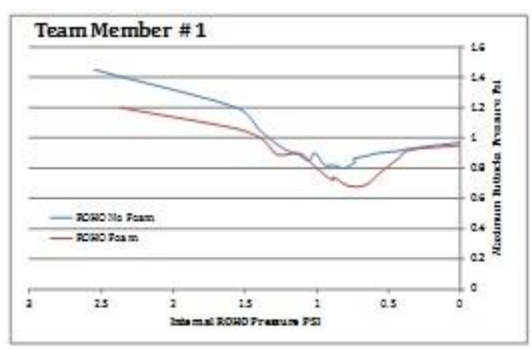

Fig. 21.22. Cushion's internal pressure vs. buttock pressure.

DEVICE TO ASSIST IN LOADING/UNLOADING A WHEELCHAIR INTO A VAN

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INTRODUCTION

The objective of this project is to develop a system that would aid a client, who only has one leg, in loading and unloading her wheelchair into her van. Since the client does have full use of one of her legs, she is able to get out of her wheelchair and stand next to the van and ultimately get into the passenger seat and transfer herself to the driver seat. The design employs a winch to pull a platform into and out of the van. Two sets of aluminum channels are used. One extends at an angle from the van to the ground and one is attached to a base plate fixed in the van. At the end of the two sets of channels is the moving platform assembly where the chair is harnessed. The winch, which is mounted on the fixed base plate inside the van, pulls the moving platform assembly into the van. A ramp is attached to one end of the platform assembly to allow the user to roll her wheelchair onto the platform. A T-shaped support bar was attached to the other end of the platform assembly to secure the wheelchair. To unload the wheelchair, tension releases from the winch and a spring forces the ramp to unfold. A counterweight on the wheelchair platform ensures smooth consistent unloading. This system can be removed from the van and placed in another van if desired. Figure 21.23 shows the client standing next to the van with her wheelchair rolled onto the platform. Figure 21.24 shows the winch mounted to the fixed base plate. Figure 21.25 shows a close-up view of the moving platform assembly.

Fig. 21.23. Client using the system to load/unload her wheelchair in the van.

Fig. 21.24. Winch placement in the van.

SUMMARY OF IMPACT

The client only has one leg yet is still very mobile. She lives by herself and is not able to travel to and from her home without an assistant. The client needs this assistant to help load and unload the wheelchair into the van since she is not able to do so herself. The developed system allows the client to load and unload her wheelchair without the assistance of another person. The final design involves the client riding her wheelchair onto the platform and strapping the wheelchair to the platform. Then the client can use her functional leg to get out of the wheelchair and into the passenger door. There, switches are used to activate the winch to load and unload the wheelchair without assistance. The client then transfers herself from the passenger seat to the driver seat. The entire device is attached to a single plate which is bolted to the studs that normally secure the rear bucket seats to the van. This allows easy transfer from one van to another if it is so desired in the future. With this design, the client can enjoy the freedom of leaving and returning home without the need of an assistant.

TECHNICAL DESCRIPTION

Safety, reliability, portability, and ease of use were all factors which were considered in the design of the final system. The final design is broken down into three sections. The first section is the platform and its assembly and this is where the wheelchair is positioned during the loading and unloading process. The second section is the set of rails in which the platform rides. The last section is the fixed base which is bolted to the floor of the van. The base also contains a set of rails to help guide the platform as well as a 2000 pound winch which is used to pull the platform assembly.

The platform was constructed using expanded steel as the flooring to increase traction and reduce weight. Three inch 6061-T6 aluminum channel was used for the intermediary section, for the rails on the fixed base plate, and for the platform assembly on the outside side edges of the moving platform. 1.5″ 6061-T6 aluminum square tubing was welded on the ends of the aluminum channels of the moving platform, and closest to the van, 1.5″. Six 2.5″ polypropylene wheels were used in this system: four were attached to the moving platform and mounted on the 1.5″ square tubing, and two to the inside ends of the intermediary section. Aluminum diamond plate was used as the fixed base which was mounted inside the van using the studs where the seats of the van would normally be fastened. A T shape support bar was added at the end of the platform assembly (the end closest to the van) with two straps at each end to secure the wheelchair onto the platform. A ramp was mounted to the platform assembly to allow the client to roll onto the platform.

Structural analysis was performed using SolidWorks on the different components of the system. The critical loading condition studied was when the platform just rises off the ground. At this position, the maximum stresses calculated were much lower than the yield stress of the 6061-T6 aluminum corresponding to a large factor of safety.

Fig. 21.25. Close up view of the moving platform assembly.

To ensure overall safety of this device, an electrical circuit was also implemented. The electrical aspect of this design contained a circuit breaker to act as a load sensor, relays to control polarity of the winch, and a magnetic switch to shut off the winch when the platform was all the way inside the vehicle. The circuit breaker/load sensor is to ensure that the device cannot be run if someone or something too heavy is on the platform. The relays allow an easy transition from the loading and unloading process by reversing the direction of the winch. Lastly, the magnetic switch was used so the winch could not be powered when the device was all the way in the vehicle. This would prevent using excess power and binding up the winch or damaging the device. No permanent modifications were made to the van so it can be returned back to stock.

The total cost of material was approximately $700.00.

EXERCISE EQUIPMENT MODIFICATION FOR THE TOLEDO SOUTH YMCA/JCC

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INTRODUCTION

The objective of this project is to develop and implement modifications to current exercise equipment that will allow use of the machine for a wheelchair user without inhibiting use without a wheelchair. The exercise equipment consists of two sides, a standing side and a seated side. Both sides have weight plates used to adjust weight. The sides operate separately from each other. The standing side, shown in Figure 21.26, uses a back rest and a stationary overhead pulley. This setup requires the user to stand with their back to the machine and perform a triceps extension. The seated side, shown in Figure 21.27, has an adjustable seat and lap bar to secure the users while performing lateral pull downs. This exercise is similar to pull-ups or chin-ups.

Both sides of the equipment were modified to promote wheelchair accessibility. The standing side was modified by removing the back rest and overhead pulley. Instead of being designed to perform the triceps exercise, this side was changed to resemble a modern adjustable hi/low pulley system. These systems allow the user to change which exercise they do by moving the pulley system up and down. This is a widely used concept in modern exercise equipment that is both convenient and reliable. This modification changes where the user pulls or pushes from, offering a wider variety of exercise options for the user while also promoting greater wheelchair accessibility. The modified standing side is shown in Figure 21.28. The seated side was also modified to allow wheelchair accessibility while performing pull-up exercise. Since the seat was the only part that prevents a wheelchair from accessing this side, the seat and part of the frame leading to the seat were placed on a hinge that folds the seat back towards the machine. When the seat is folded in this way, a wheelchair can fit underneath the lap bar. No modifications to this lap bar were required to secure a wheelchair user. While in the wheelchair, the user can still reach the overhead fixture to begin the exercise. The modified seated site is shown in Figure 21.29. The changes made to the machine did not inhibit previous use of the equipment.

SUMMARY OF IMPACT

The equipment is housed at the Toledo South YMCA/JCC at Morse Center on the University of Toledo Health Science Campus. The wheelchair users for this operation are assumed to have complete upper body mobility. When working out, these individuals must physically get out of their wheelchairs to seat themselves in the station they want to work out at. This tends to be a very long process for any person using a wheelchair. The current process of moving from machine to machine also forces others to slow down their workouts. The modifications done to the equipment allows wheelchair users to easily work out without inhibiting other users.

TECHNICAL DESCRIPTION

Modifications were performed on both sides of the machine. Main concerns were safety and reliability. The backrest and the overhead pulley of the standing side were removed. This side was then revamped to an adjustable high/low pulley weight machine. Standard 6” weight lifting pulleys and cable were used for this purpose. An extension bar attached to a spring loaded pin was used to allow a person sitting in a wheelchair to adjust the pulleys while seated. The seated side was modified to keep the seat out of the way of a wheelchair user by utilizing a straight arm chair swing. The frame for the seat directly below the lap bar was cut and reattached with a very heavy duty, 3” high surface-mount hinge. This allows the chair to swing 180° completely out of the way and allow wheelchair access. Several donations were secured from different sources, and the actual total cost of parts was about $400.

Fig. 21.26. Standing side of the original machine.

Fig. 21.27. Seated side of the original machine.

Fig. 21.28. Modified standing side of the machine

Fig. 21.29. Modified seated side of the equipment.

CHAPTER 22
UNIVERSITY OF WYOMING

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ASSISTIVE TECHNOLOGY FISHING DEVICE

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Client Coordinator: Peter Pauwels, Accessible Fishing
Supervising Professor: Mr. Scott Morton, Research Scientist, PE
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INTRODUCTION

The assistive technology (AT) field aims to improve the lives of people with mental and physical disabilities by providing technological devices to aid them in various tasks ranging from every day activities to hobbies and recreation. The field is constantly growing, and due to increased interest, fishing devices are becoming more commonplace. However, the majority of these devices demonstrate poor variable distance casting and lack hooking action capabilities, failing to provide an equivalent fishing experience. According to Peter Pauwels, who has been working to improve the assistive technology field for 20 years, enhancing these particular fishing aspects in the AT fishing pole is an important advance. For this reason, the overall aim of the project was to improve both the variable distance casting and hooking functions while optimizing the structural design of the AT fishing pole. The final design uses a pneumatic rotary actuator to control the pullback, casting, and hooking of the fishing pole. The reel-in process is powered by a 12 volt DC motor attached directly to the reel. A mechanical solenoid is used to release the line automatically during the cast. Two solenoid valves control the compressed gas flow to the pneumatic rotary actuator in order to achieve the various functions. Mathematical analysis of the system model yielded the necessary torque required to cast up to 80 feet, from which all parts were appropriately sized. The AT fishing pole utilizes simple switching and readily available components to increase reliability and reduce complication. This portable machine combines safety and functionality in a package costing less than 1000 dollars to ultimately afford the sport of fishing to a much broader audience.

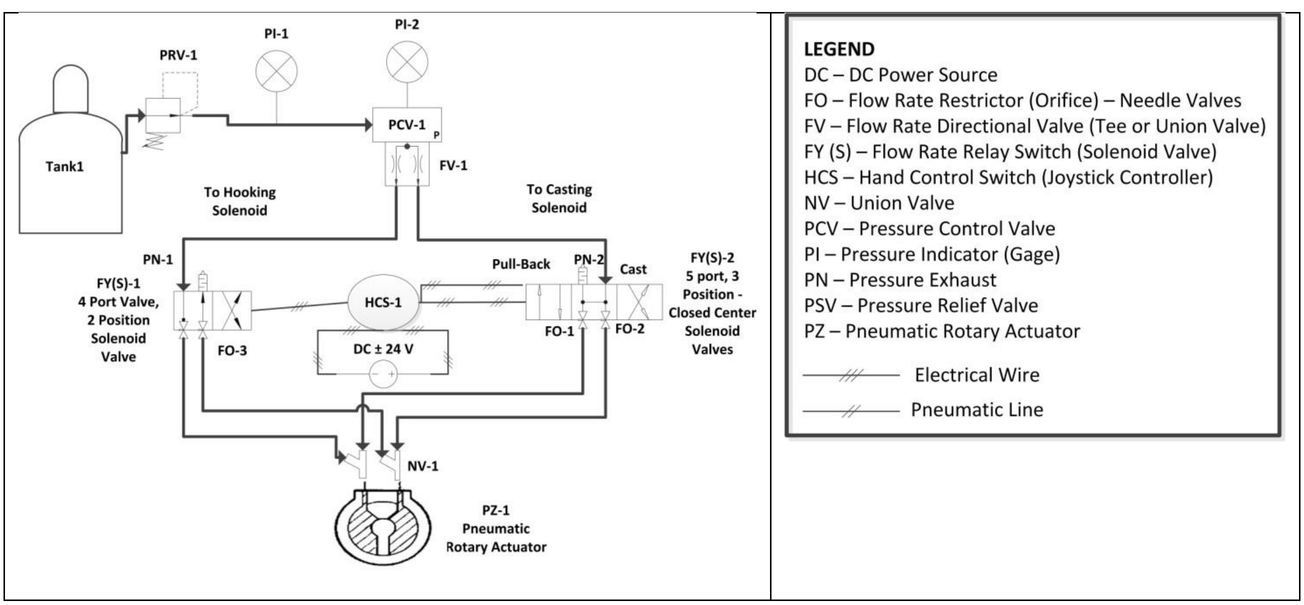

Fig. 22.1. Automated Fishing Device PID (ISA, 1992).

SUMMARY OF IMPACT

Fishing is no longer an activity solely for able-bodied outdoor enthusiasts. Modern technology in the form of assistive technology (AT) is helping people with wide ranging disabilities to actively participate in various hobbies, sports, and recreation worldwide. In addition, these devices play a pivotal role in therapeutic rehabilitation, according to Peter Pauwels, who has worked in the assistive technology field for 20 years. Mr. Pauwels has demonstrated that one such AT device, the AT fishing rod, is highly effective in accelerating the recovery process of patients undergoing rehabilitation at Craig Memorial Hospital near Denver, Colorado.

TECHNICAL DESCRIPTION

The Cast'n'Catch utilizes a single pneumatic rotary actuator to precisely control the three primary functions of the fishing pole. The reel is powered by a 12 volt DC motor, and a mechanical solenoid is used to release the line at an adjustable angle automatically during the cast. Two solenoid valves control the compressed gas flow to the pneumatic rotary actuator in order to produce the various functions. The AT Fishing Device utilizes mechanical switches and industrial grade components to increase reliability and reduce complication.

Pneumatics Design. The Piping and Instrumentation Diagram (PID) of Figure 22.1 demonstrates the flow sequence during normal operation of the automated fishing device. The compressed gas travels first through a pressure regulator located directly on the tank. From this regulator, a 3/8″ nylon pneumatic line directs the gas to a second pressure regulator easily accessible by the user to allow for convenient changes in pressure to assist in variable distance casting. The compressed gas is then split and re-directed by an inline tee reducer fitting into a 3/8″ line for the casting solenoid valve, and a 1/4″ line for the hooking solenoid.

Several solenoid valves were considered to achieve the desired casting and hooking functionality from the machine. A 4-way, 3-position double-solenoid valve with a closed-center allows full control of the casting sequence. By activating either one of the two momentary contact switches controlling the valve, the solenoid will be opened to rotate the rod into casting position. When the switch is released, a spring returns the valve to the closed center position, holding the current pole position. Upon activation of the second switch, the valve quickly exhausts the compressed gas, accelerating the fishing pole and casting the lure.

A 3 way, 2 position single-solenoid valve controls the hooking sequence. In the normal, inactive position the valve is closed which has no effect on the system. The activation of an electrical switch opens the valve, releasing a sudden burst of pressure to cause quick rotation of the actuator arm and fishing pole away from the casting direction, essentially setting the hook.

From the solenoid valves, each pneumatic line will pass through a manual flow control valve of appropriate size to allow more precise onboard control of the particular functions. The ¼ inch tubing from the hooking solenoid is routed through a union check valve, to ensure pressure from the casting sequence does not exhaust through this line. A union valve also helps to streamline the airflow, therefore reducing pressure losses through the line. A plug-in reducing fitting converts the 3/8 inch line into a 1/4 inch line before the final connections to the actuator.

The tubes associated with pull back and hooking combine through a 1/4 inch male y-valve fitting. The remaining two 1/4 inch male straight valves are converted through a 1/4 inch NPT (National Pipe Thread) female – 1/4 inch BSPT (British Standard Pipe – Tapered) male adapter. These BSPT adapters thread directly into the pneumatic actuator, which specifies Rc 1/4 inch female port sizes, equivalent to 1/4 inch BSPT thread.

The onboard pressure gage and the two solenoids, as well as the corresponding electronics are located in a protective, NEMA rated control box mounted to the stand. They are protected from weather and water, to ensure extended functionality of the fishing machine. In addition, the compact box optimizes the spatial organization, protects the electrical components, and increases portability. The part arrangement within the box is also designed to avoid kinks and sharp angles in the pneumatic tubing to minimize potential losses through the pneumatic line and fittings.

Control System Design. There are five processes that are controlled electrically for use of the AT Fishing Device: the Pullback Process, Casting Process, Line Release Process, Hooking Process, and Reelback Process. These processes allow the user to control the fishing rod with minimal physical input. The purpose for each process along with how it is controlled is described in the following sections.

- Pullback Process. Imagine a fisherman casting into a river. The first movement is to rotate the rod backwards. The purpose of this movement is to give the fisherman enough angle of rotation during the forward cast to reach a certain rod speed, hence launching the lure to an intended distance. Mechanically, this process is powered by use of the pneumatic actuator. The actuator receives compressed CO2 from the CO2 tank via electronically controlled valves. To control the valves, a user-controlled switch is employed in the form of a joystick. Essentially, when the joystick is moved into a position where the pullback switch is activated the fishing rod will rotate backwards. To meet the variable distance casting objective, the pullback rotational distance can be varied. If the user wishes to cast a longer distance then the fishing rod can be rotated further backwards.

- Casting Process. After rotating the rod backwards, a fisherman's rod is rotated forward to accelerate the lure to the intended angular velocity. In the AT Fishing Device, this is accomplished by the same pneumatic actuator as the Pullback Sequence except the pneumatic valves are in a different configuration. This allows the pneumatic actuator to receive compressed CO2 at a greater pressure and through different ports creating a larger torque and in the opposite direction of the Pullback Sequence. Similar to the Pullback Sequence, the user interface control for this sequence comes from positioning the joystick in a way that activates a momentary-contact switch. This switch activates a certain pneumatic valve configuration to control the pneumatic actuator. The angular velocity of the rod is dependent on the amount of rotational distance in which the pneumatic rotary actuator can put work into the rod. The extent of rotational distance is dependent on how far the user has rotated the rod back during the Pullback Sequence.

- Line Release Process. At some point during a forward cast into a river, the fisherman releases the line brake on the reel which allows the fishing line out and lets the lure launch as a projectile. The AT Fishing Device has an automated Line Release Process. This is accomplished by using a cam-activated electrical switch and an electrical solenoid pulling the reel's brake release. When the cam reaches a certain position, it closes a momentary contact switch which activates a mechanical solenoid. This mechanical solenoid puts a tensile force on a bell-crank connected to the line brake on the reel. When the mechanical solenoid is activated the line brake is subsequently released. The fishing line should only be released during the casting process. Since the cam rotates synchronously to the fishing rod it activates the push on switch during other processes during the fishing cast. To prevent the line brake from being released, the circuit was set up in a manner that the electrical solenoid can only be turned on when both the casting joystick switch and the cam-activated switch are activated.

- Hooking Process. Once a fish bites the lure, a fisherman rotates the fishing rod backwards, away from the fish. This puts extra tension in the fishing line which will then set the hook. The AT Fishing Device sets the hook by rotating the rod backwards using a similar process to the Pullback Process. When the user activates a switch on the joystick, pneumatic valves are actuated. The valves send pressurized CO2 to the pneumatic actuator. The actuator then puts a torque on the fishing rod which will rotate it backwards. The torque for the Hooking Process is greater than the torque needed during the Pullback Process in order to create extra tension in the fishing line for when the user would like to hook a fish.

- Reelback Process. The Reelback Process for the AT Fishing Device is activated when the user pushes the reel back switch on the joystick. This switch asserts a DC motor which drives a belt. This belt then turns the reel which pulls the fishing line in.

Circuit Design. Figure 22.2 illustrates the circuit configuration employing four manual switches and one automatic switch (which is activated by the line release cam). The four switches, located in the user interface joystick, are mechanically constrained so the Pullback, Hooking, and Casting Processes do not occur simultaneously. This circuit is configured such that the Line Release Solenoid can only be actuated if both the Casting Switch and Line Release Switch are closed. A connector attaches the joystick to the control panel. This connector allows for the use of multiple user interfaces which allows for people with varying degrees of mobility to use the AT Fishing Device.

The cost of parts/material was about $1200. A mechanical diagram of the AT Fishing Device is provided in Figure 22.3.

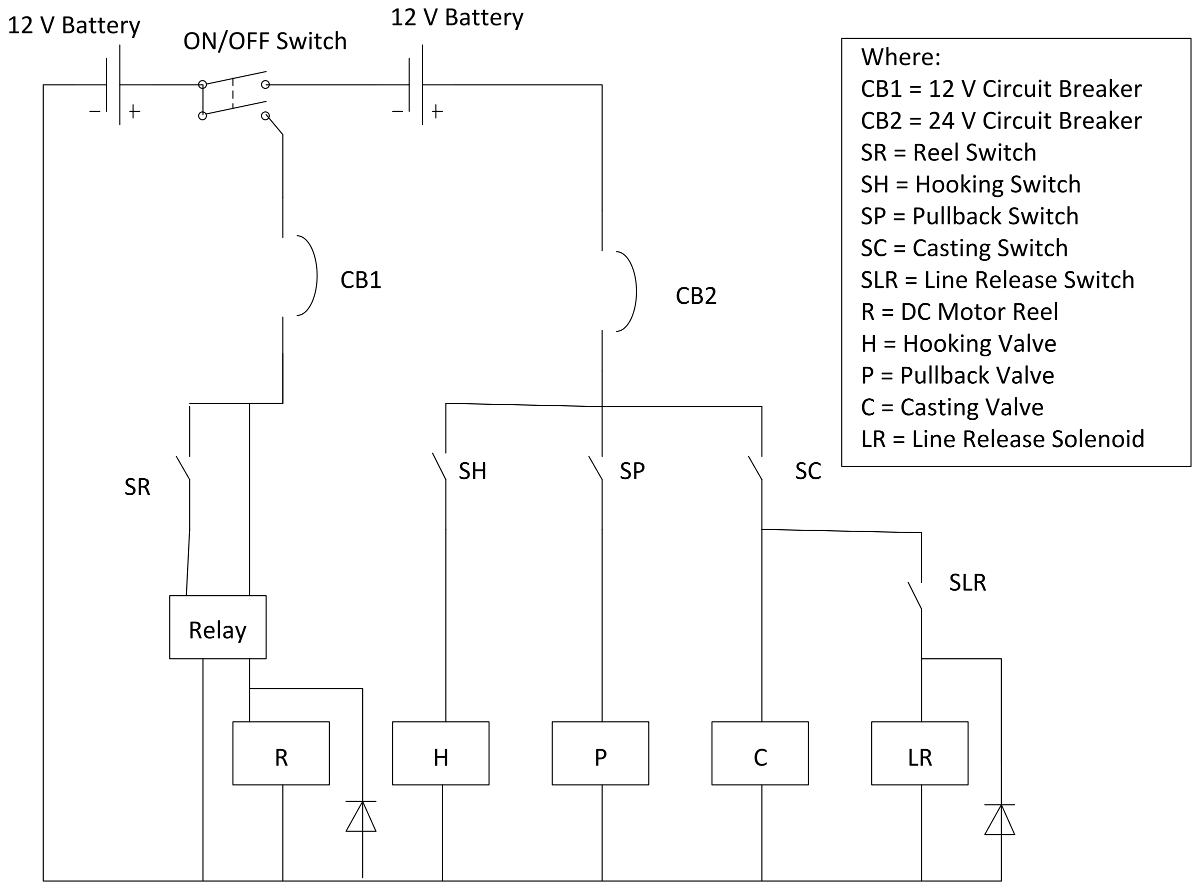

Fig. 22.2. Control system circuit and circuitry component locations for the AT Fishing Device.

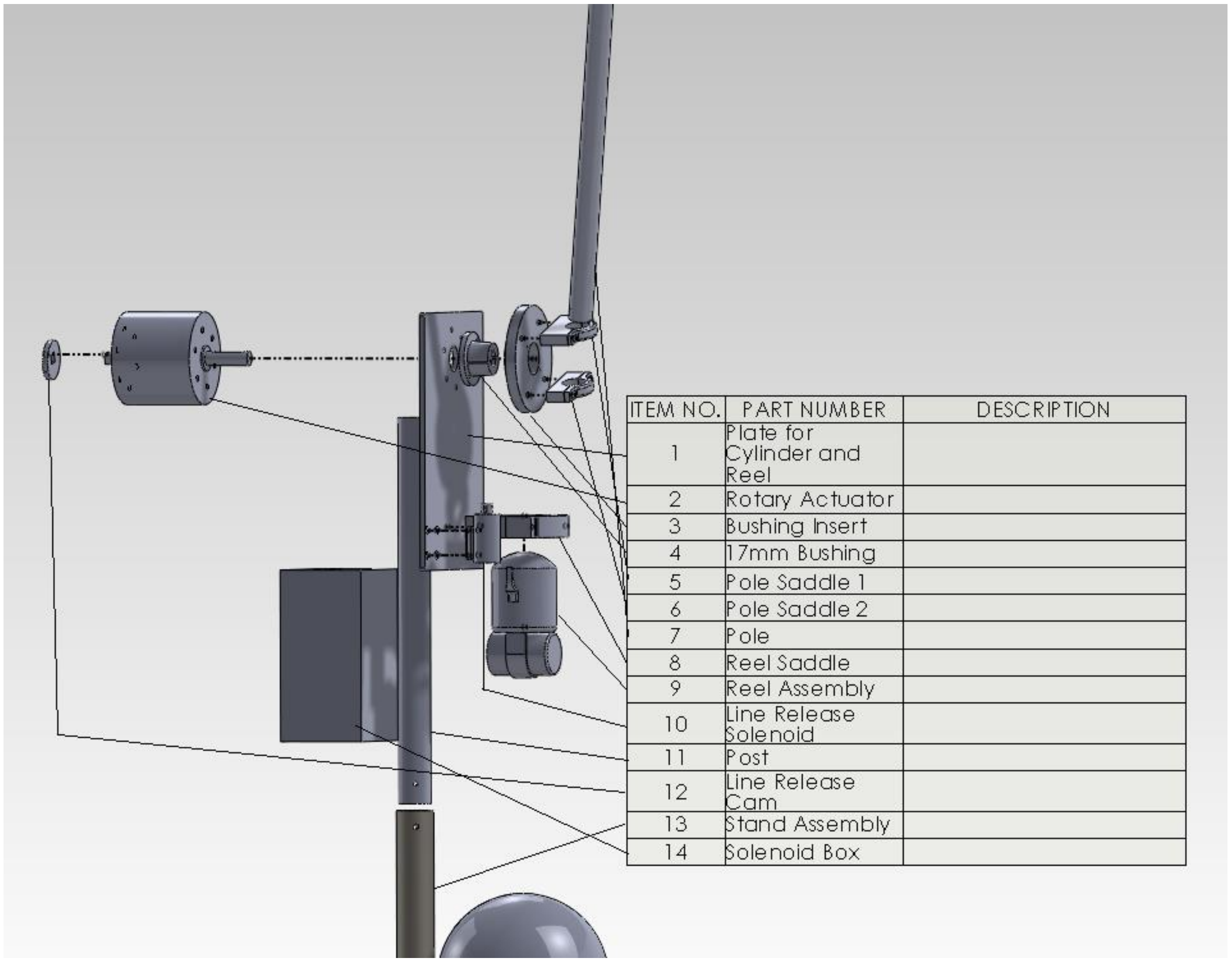

Fig. 22.3. Mechanical diagram of the AT Fishing Device.

COMMUNICATION DEVICE FOR THE HEARING/SPEAKING IMPAIRED

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Client Coordinator: Sandy Root-Elledge, M.A., Associate Director for Program Development, Wyoming Institute for Disabilities (WIND)
Supervising Professor: Dr. David Whitman, Ph.D., P.E. Electrical and Computer Engineering Department, Department 3295 1000 E. University Avenue, Laramie WY 82071

INTRODUCTION

A two way system was developed to enhance communication between two hearing, or speech, impaired individuals. The device is contained within two wirelessly connected keyboard equipped units for use between two individuals seated from 0 to at least 20 feet from each other. A user can type their desired communication on one of the attached keyboards. The device will then output the communication stream as both text and speech for the other user to read as well as hear.

SUMMARY OF IMPACT

The two way communication device allows communication between two individuals and includes the following features:

- Accepts input from two users
- Provide textual and/or audio output with the ability to vary output characteristics (i.e. voice, pitch, volume, etc.)
- Stores 2GB of conversations data
- Wireless transmission between two devices
- Liquid crystal display (LCD) output

TECHNICAL DESCRIPTION

The communication device developed for the hearing/speech impaired was implemented using two each of the following in Table 22.1.

Each device component communicates serially with the microcontroller via a USART port. The Atxmega64A3 microcontroller was chosen due to its available seven USART ports, however, only four USART ports were required. The microcontroller is field programmed though a PDI port which is included in the PCB design.

Table 22.1

Atxmega64A3 microcontrollers from Atmel	VIP-345 Keyboard Scan Code to ASCII Code Converters
VStamp text-to-speech (TTS) converters from RC Systems	RS-II Serial Interface Adapters from AWC Electronics
4X20 liquid crystal display (LCD) Screens from LongTech Optics	TQFP64 to DIP64 Adapters from Proto Advantage
XBee Transceivers from Digi International	3” 1 Watt Speakers
PS/2 Keyboards	8.66” x 6.5” x 3.35” ABS Plastic Enclosures
12V DC Power Switches	Switching Mono Headphone Jacks
5v, 2.5A, Power Supplies from Vetra Systems	VIP-345 Keyboard Scan Code to ASCII Code Converters

The VStamp TTS was chosen because of its serial communication abilities. Additionally, the module offers a wide swath of command sets and ample audio output power through its internal 1W amplifier. Interfaced through a microcontroller USART port, the VStamp reads incoming ASCII characters, converts the strings, and outputs speech through a speaker. The VStamp operates at a 9600 Baud rate and is supplied with 3.3 V.

The 4X20 LCD screens were also implemented due to their serial communication abilities and breadth of controllability through the command sets. The LCDs are interfaced with the microcontroller through a USART port at a 9600 Baud rate, no parity, and 1 stop bit.

The XBee wireless transceivers were selected due to the ease of interfacing them serially with the microcontroller. The transceivers operate at 3.3v, receive the incoming ASCII characters at a 9600 baud rate, no parity, 1 stop bit, and transmit at 2.4 GHz. Essentially, they created a direct wireless pipeline between the two devices. Wireless flow control was accomplished in programming through microcontroller interrupts.

The PS/2 keyboards were selected as they were the customer's preference. The customer preferred full sized keyboards and a PS/2 connection was required in order to interface the keyboards with the VIP-345. Therefore, a user may use the PS/2 keyboard provided or purchase another which suits them better.

The VIP-345 is an essential aspect of the completed design. The VIP-345 not only brings in power to the entire device, but it allows a user to connect a standard PS/2 keyboard. This keyboard signal is then split such that the signal is routed to the RS-II Serial Interface Adapter via a DB9 connector and a PC via a separate PS/2 female-female connector. The VIP-345 outputs ASCII 8 bit character strings at a 9600 baud rate, no parity, and 1 stop bit. The RS-II serial interface adapters create the link between the VIP-345's and the microcontrollers on the designed PCB's. After the ASCII signal is received from the VIP-345, the RS-II converts the RS-232 to 3.3V TTL such that the keyboard signal may communicate with the ATxmega64A3 microcontrollers.

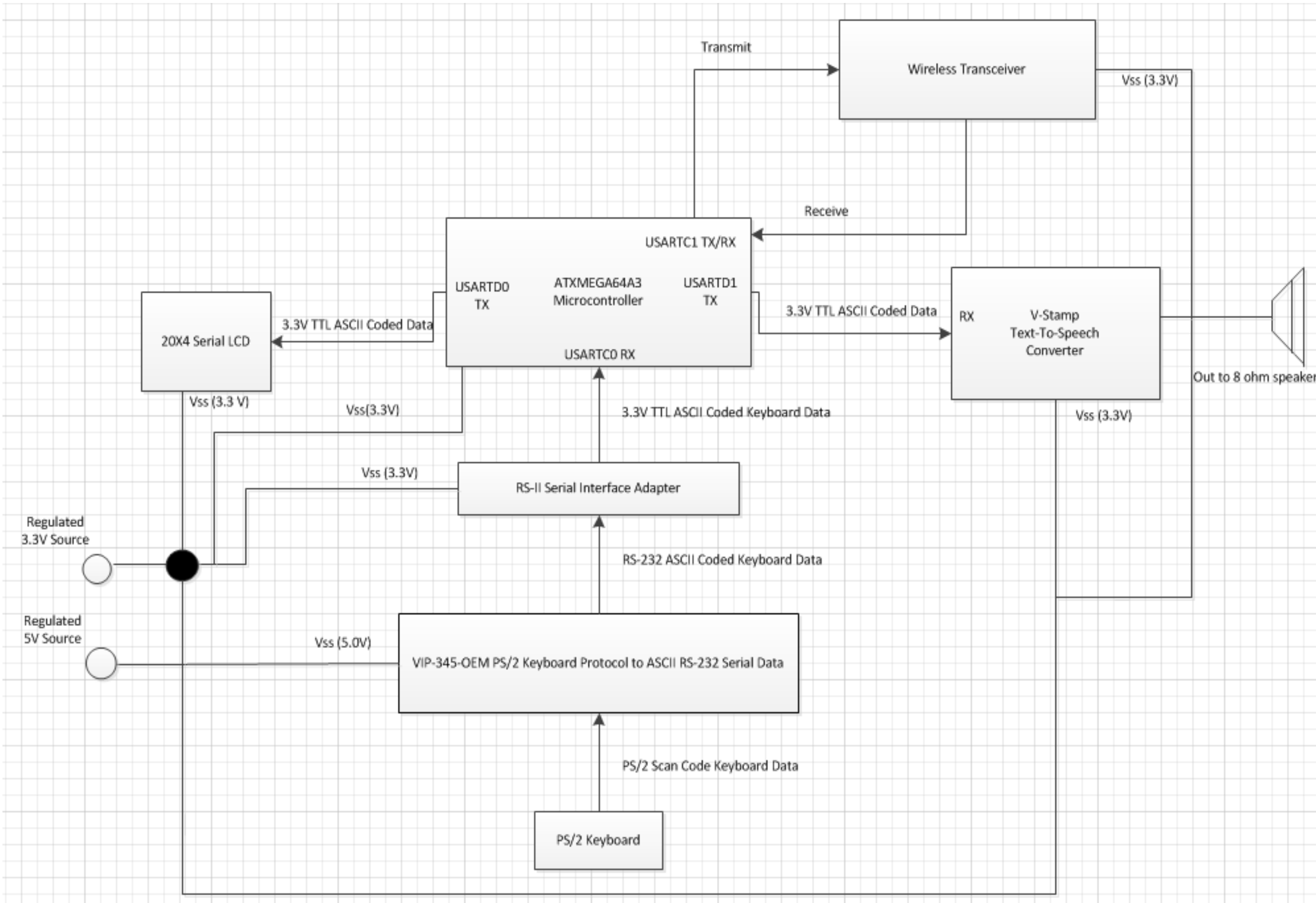

Fig. 22.4. Block diagram of the two way communication system.

Fig. 22.5. Completed prototype (photo courtesy of J. Barrett, 2012).

MECHANICAL SHAFT ENCODERS FOR A "SMART" WHEELCHAIR

Designers: Kathleen M. Shea, Dana L. Schultz
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Supervising Professor: Dr. Steven F. Barrett, Ph.D., P.E., P.E. Electrical and Computer Engineering Department, Department 3295 1000 E. University Avenue, Laramie WY 82071

INTRODUCTION

In the last few years, the field of assistive technology has made significant advances. A commonly researched assistive device is the autonomous wheelchair. Advancements in autonomous wheelchairs will benefit many. Not all users can operate powered wheelchairs with traditional joystick controls due to lack of mobility and strength of the wrist and hand. For those individuals, there are currently very few options. One possible alternative to the traditional mechanical wheelchair is the automated or "smart" wheelchair. The "smart" wheelchair allows individuals that cannot operate the traditional joystick more mobility because it can be tailored to the individual's needs. "Smart" wheelchairs are not widely available and tend to be expensive. Research has been ongoing at the University of Wyoming on a "smart" wheelchair. A crucial step in the design of such a system is monitoring the wheelchair's distance travelled and direction of motion. This project developed an odometer that mounts on the inner side wheel of a powered wheelchair to provide better doorway clearance.

SUMMARY OF IMPACT

The designed odometer consists of an encoder disk and a sensor system that can be mounted interior to the wheel. The total cost of the designed odometer is significantly less than that of off-the-shelf mechanical shaft encoders.

TECHNICAL DESCRIPTION

An encoder-based odometer can be used to measure distance travelled and velocity. Transitions between different materials or colors on an encoder disk are sensed. A microcontroller is used to count the number of transitions and store the elapsed time. From these data, the distance travelled and velocity can be determined. The first step in designing the odometer system was to select a sensor that would provide a signal that could be used to calculate velocity. We chose the Fairchild QRD1114-ND sensor that contains an IR emitter and a NPN silicon phototransistor. When the radiation emitted from the diode is reflected off an object or surface the phototransistor responds. This sensor has a rise and fall time of 10-50 μs and is less than $1.50. Using operational amplifiers in a threshold configuration provided a fairly clean signal.

The sensors are housed in a shielded box with a half inch between the centers. The size of the shielded box is restricted by the requirement to mount the sensors between the wheelchair frame and the wheel. A prefabricated box was purchased and customized to house the sensors by milling them down to an appropriate size. The shielded box provides protection from motor noise and the elements.

Fig. 22.6. Mounting location for sensors.

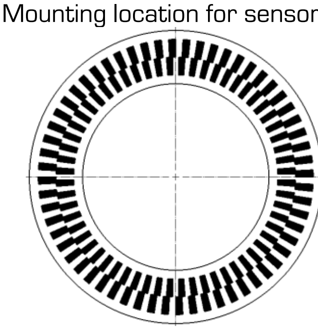

Fig. 22.7. Encoder disk.

Once a sensor was selected, an encoder disk was designed. The original design consisted of two overlaid metal disks. The bottom disk was textured and painted matte black. The top disk was painted white and consisted of two staggered channels with multiple segments. Two channels are used to detect the direction in which the wheelchair is moving. With the white and black disk, the voltage outputs from the sensor were very similar and close to zero, making differentiation between the signals difficult. The original design of the top disk was improved by replacing it with mirrored stainless steel. Sixty segments allow for a signal with a resolution of 0.124 inches. The sensor has a rise time of 10 μs and a fall time of 50 μs, which makes the sensor capable of providing a clean output at full speed. With this response time, more than 120 segments could have been used but 120 allows for ease of calculations. A diagram of the encoder disk can be seen in Figure 22.7.

The output from the sensor circuitry was then interfaced with a microcontroller for rapid calculations. With the encoder disk mounted on the interior of the wheel and the sensor mounted directly across from it, the transition between the black and silver can be used to calculate the distance travelled and the velocity using the time between transitions. These calculations can then be stored. When channel A (outer sensor) transitions from silver to black, channel B (inner sensor) sees either silver or black, depending on the direction of motion. When the wheel is moving clockwise, the transition from black (high voltage) to silver (low voltage) occurs while channel B is black. When the wheel is moving counterclockwise, the transition occurs while channel B is silver. This is shown in Figure 22.8. The direction of motion, as determined by the microcontroller, was designated by the sign of the velocity and direction; positive indicating forward motion, and negative indicating backward. Code was written to determine the direction, distance travelled and velocity.

After initial testing and verification, the system was mounted to a Quickie P300 powered wheelchair for testing. A mechanical shaft encoder was also mounted to the wheelchair for comparison in testing. The signals obtained by the encoder disk and sensor system are comparable to the signals from a mechanical shaft encoder.

Acknowledgements

Portions of this report appear in proceedings of the 2012 Rocky Mountain Bioengineering Symposium. Presented at Rocky Mountain Bioengineering Symposium & International ISA Biomedical Sciences Instrumentation Symposium Hosted by Virginia Tech - Wake Forest School of Biomedical Engineering and Sciences Blacksburg, VA, 22-24 March 2012.

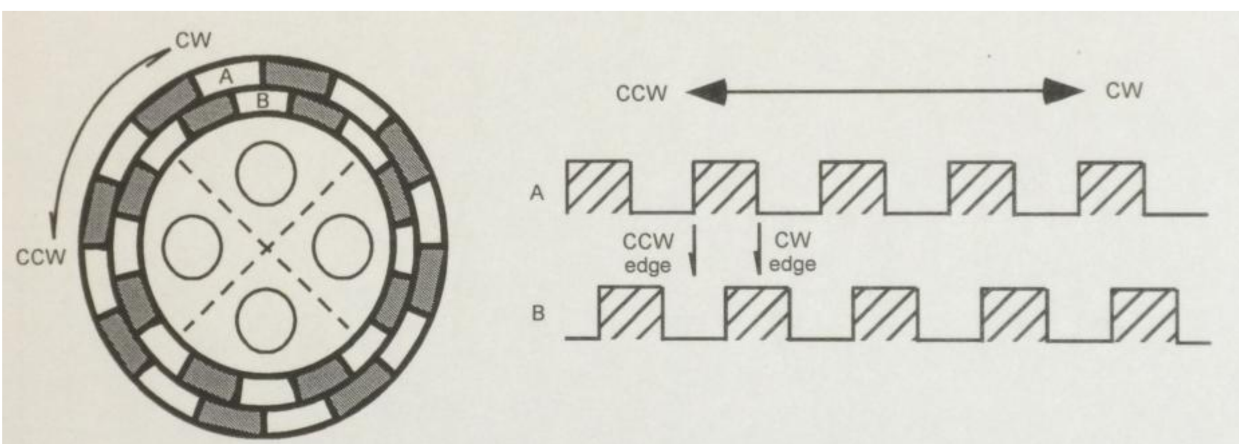

Fig. 22.8. Determining Encoder Disk Direction of Motion.

MAPPING AND NAVIGATIONAL CONTROL FOR AN AUTONOMOUS WHEELCHAIR

Designers: Dana Schultz and Kathleen Shea
Client Coordinator: Client Coordinator: Steven F. Barrett, Ph.D., P.E.
Supervising Professor: Dr. Steven F. Barrett, Ph.D., P.E., P.E. Electrical and Computer Engineering Department, Department 3295 1000 E. University Avenue, Laramie WY 82071

INTRODUCTION

Typical powered wheelchairs provide a means of transportation for many with limited mobility. However, the traditional joystick requires full mobility of the hand and wrist in order to be operated safely, leaving those without this dexterity no viable transportation option. Autonomous "smart" wheelchairs attempt to fill this gap. A "smart" wheelchair is an autonomous device; capable of navigating through a person's home or office with little user input. "Smart" wheelchairs are designed to work with a variety of interface options, providing those with limited dexterity alternative means to control their wheelchair. The goal of this project was to determine methods for mapping and navigational control for the wheelchair. The control system acquires data from eighteen sensors and uses the data to navigate around a pre-programmed map. The map is stored on a micro SD card. The control system also provides user interface in the form of a touchscreen LCD. This designed system will be an easy to use and cost effective alternative to current autonomous "smart" wheelchair technology.

SUMMARY OF IMPACT

The flexibility and complex design of autonomous wheelchairs have made those currently available expensive. Ongoing research has been aimed at designing a cheaper, alternative control system that could be easily attached to a powered wheelchair.

TECHNICAL DESCRIPTION

The University of Wyoming has engaged in an ongoing research effort to develop an autonomous wheelchair. The project has been partitioned into a number of subsystems as shown in Figure 22.9. Students have worked on various subsystems as summer projects and also senior capstone design projects. In this research project the overall system was defined and several subsystems were completed.

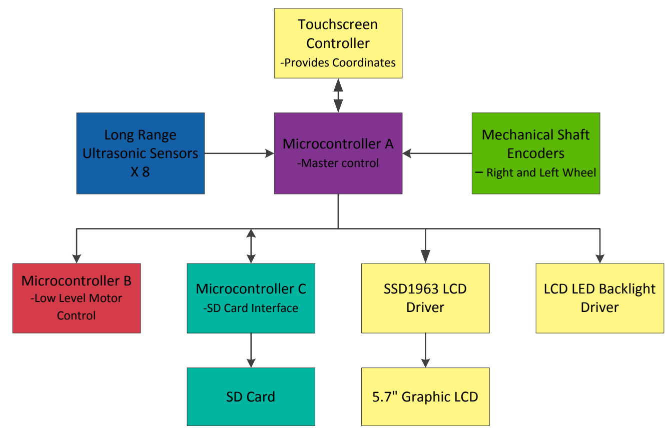

Fig. 22.9. Overall System.

Overall the system contains a map of its environment stored on an SD card. It will navigate about its environment in response to user input via the Touchscreen Controller, ultrasonic sensors that indicate the presence of walls and obstacles and mechanical shaft encoders providing distance traveled information. The computational load is shared between three microcontrollers (A, B and C). Microcontroller A serves as the master controller and coordinates system operation. Microcontroller B provides for low level motor control while Microcontroller C coordinates SD card operations. For this project effort, the Touchscreen Controller, long range ultrasonic sensors and the mechanical shaft encoders were developed. System integration is an ongoing research effort.

User Interface. The user interface for this system requires user input as well as feedback to the user in the form of a display. Traditional push buttons with a graphic liquid crystal display (LCD) were considered for this application. However, push buttons require application of considerable force at a specific angle. This would limit the usability of the system for users of limited mobility. A traditional menu system would also introduce complexity for the user as they try to select a destination. As an alternative, a touchscreen LCD was employed. The selected model was the New Haven Display 5.7-320240WFB-CTXI #-T-1. The selected model has an internal driver that communicates with the microcontroller and handles the timing of signals sent directly to the display. Additional hardware allows the LCD to be LED backlit. The microcontroller sends a pulse width modulated (PWM) signal to control the brightness of the LED's. The selected touchscreen controller communicates with the microcontroller via SPI. When the user touches the LCD, the touchscreen controller triggers an interrupt on Microcontroller A via external interrupt INT0. The microcontroller then sends commands to the touchscreen controller, indicating which coordinate information it wants. The touchscreen controller performs an analog to digital conversion and sends the data back to the microcontroller. Since resistive touchscreens take time to settle, a delay is introduced in code between the triggering of the interrupt and the beginning of the communication with the touchscreen controller. The touchscreen LCD is used to provide all user interfacing for this system. The user will select their destination location by touching the appropriate location on a map displayed on the LCD. As the system is driving, the current position of the wheelchair will be displayed on a map on the LCD. All menu functions and options will also be handled through the touchscreen.

Obstacle Detection. Obstacle detection is an important feature for the autonomous wheelchair and sensors are needed for safe navigation. The sensors can be used for navigation through doorways and docking with furniture as well as obstacles such as columns in a hallway. Our system uses eight ultrasonic sensors for obstacle detection. We used the Ultrasonic Range Finder –XL-Maxsonar EZ3. A total of eight sensors were placed around the perimeter of the wheelchair.

The sensors were characterized from 24 cm to 100 cm. The sensor does not send an accurate signal under 24 cm. To compensate for this limitation, we moved the sensors in on the wheelchair frame so that the accurate readings start at the edge of the wheelchair. The ultrasonic sensors used provide the information that is needed for obstacle detection. The values from the A-D converter are consistent with the distance in cm that the object is away from the sensor.

Distance and Velocity Measurements. Accurate measurements of distance and direction travelled are essential in the accuracy of the navigational system. Koyo TRD-S360 light duty incremental shaft encoders were selected for this purpose. The encoders are mechanically connected to the exterior of the left and right wheels on the wheelchair. The encoders output pulse trains with each pulse corresponding to one degree of rotation. The direction of motion can be determined using two signals offset by 90° provided by the encoder. The encoders also provide noise minimization by outputting complement signals (A' and B') for each pulse train. Connecting these signals to a differential amplifier will reduce the noise created by the wheelchair's motors. The selected differential amplifier is the INA2134PA-ND. This amplifier was selected for its low distortion, high CMRR, and fixed gain of 0 db.

To demonstrate the functionality of the encoder system a demo program was written. This program uses the information from the shaft encoders to track the wheelchair's position and displays this information to the LCD. The wheelchair is represented by a small square on the screen. As the wheelchair drives forward, a green line is drawn on the screen relative to the speed and amount of motion in the forward direction. Reverse motion follows a similar procedure, except the drawn line is red. For left turns, a magenta square is drawn and for right turns a cyan square is drawn. As mentioned previously, work is ongoing to integrate system components and develop the overall navigation algorithm.

Acknowledgements

Portions of this report appear in proceedings of the 2012 Rocky Mountain Bioengineering Symposium. Presented at Rocky Mountain Bioengineering Symposium & International ISA Biomedical Sciences Instrumentation Symposium Hosted by Virginia Tech - Wake Forest School of Biomedical Engineering and Sciences Blacksburg, VA, 22-24 March 2012.

CHAPTER 23
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ACTIVE REACH AND MANIPULATION (ARM) CLINIC: THERAPEUTIC DEVICES AND SYSTEMS

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INTRODUCTION

There are elements of four projects represented herein. 1. Generic End-effector fixture, 2. Grip Force and Wrist Rotation Game, 3. Bubble Game, 4. xAr exoskeleton frame.

The Active Reach and Manipulation (ARM) clinic was initiated in Spring 2011, providing sophisticated rehabilitation services to underserved people with stroke and significant movement limitations (SML). The ARM clinic serves metro Detroit residents with no or limited health care insurance for rehabilitation following a stroke, spinal-cord injury or other neurological injury or disease. The ARM clinic is a collaboration between Occupational Therapy and the Enabling Technologies Laboratory.

The use of robotic devices in therapy can be traced back to the earlier work of Erlandson [1] and more recently an influx of systems [2-4]. The upsurge in the use of robotics in therapy has been stimulated by research demonstrating the neuroplasticity of the central nervous system [5-7]. Keys to motor recovery via neuroplastic rewiring of the motor cortex are a high repetition of voluntary movements and engagement in a task that is motivating and challenging to the patient [7]. Robotic systems are ideally suited for presenting the consistent stimuli for highly repetitive tasks and gathering performance data. More difficult is the design and creation of an environment, therapeutic tasks and exercises that maintain the patient's engagement for the time and repetitions required for neuronal rewiring. The ARM Clinic is obtaining and creating materials that address the requirements for successful therapeutic interventions and protocols based on neuroplasticity. Four projects are described: a universal end-effector clamp, two exercise modules, and a Creform frame for mounting right and left xAr exoskeleton antigravity arms. The xAr is manufactured and distributed by Equipois and is designed for the reduction of ergonomic stress (http://www.equipoisinc.com/products/xAr/). These products will be used with ARM Clinic clients.

SUMMARY OF IMPACT

Up to the writing of this document, the xAr exoskeleton arms were installed using the Creform mounting frame and two individuals have used the system. The xAr did not meet the needs of one individual, the problem being that the individual was not able to concentrate and focus on the therapeutic tasks. The second individual demonstrated significant improvement in a very short period of time. A generic end-effector fixture was designed and built. This fixture was designed for the MH5 Motoman robot. We are still waiting for the robot and consequently have not had the opportunity to use the clamp. The clamp was designed to hold the touch screen and while two software therapeutic exercise modules were designed and implemented, they have not yet been used in the ARM clinic. These elements are planned to be made operational as soon as the robot arrives.

TECHNICAL DESCRIPTION

Generic end-effector fixture

We are designing the generic end-effector fixture to work with the Motoman MH5 robot. A variety of devices can then be attached to the generic fixture. The combined fixture and attached device form the "end-effector" for therapeutic activities. The first end-effector will use an existing device –the Biometrics, Ltd - E-LINK Upper Limb Exerciser. Utilization of the Biometrics device will enable us to very quickly try the system in the ARM Clinic under supervised and controlled conditions. An LCD monitor is mounted on the generic end-effector fixture and will be driven from the PC that controls the Biometrics unit. The generic fixture will also hold four cameras; one camera to capture the user's facial expressions and three others to capture arm, wrist and hand movements as tasks are performed. The Biometrics device has a number of attachments that target arm, wrist and hand therapy. Adding the device to the robot arm and requiring the person to reach and then perform an exercise addresses the therapeutic issues of coordinated gross and fine muscle movement.

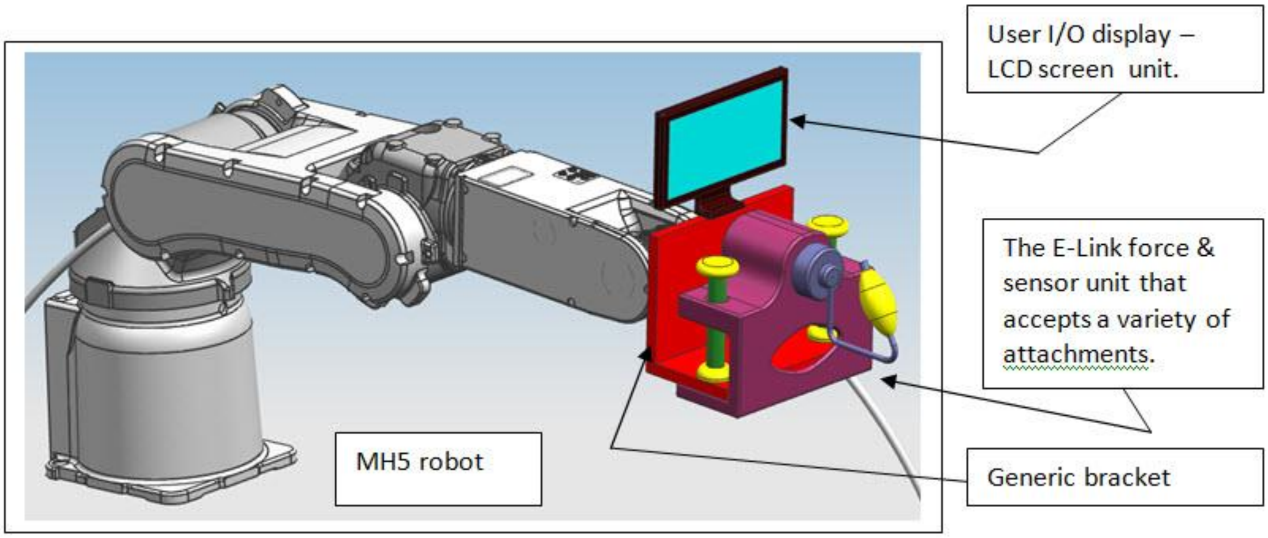

Fig. 23.1. (Top) CAD representation of MH5 and the generic end-effector holding the E-LINK. (Bottom) shows the completed generic bracket with display LCD and E-LINK mounted on an RT 100 robot. This robot is not suited for the clinical therapy sessions, but was used to verify the prototype generic fixture and E-LINK attachment.

Software Modules

The Biometrics systems use computer games to motivate the patient. For example, squeezing a handle instrumented with pressure sensors, wherein the squeezing force must be controlled and modulated to control the motion of items on a computer screen. These games are limited to the Biometrics devices and performance data is not available for downloading to a database.

In order to obtain real-time user performance data, two different software programs were written for two types of therapeutic exercise activities. One activity deals with force control during grip squeezing tasks or wrist rotation tasks, either from the E-LINK or a second hardware device still under construction. The second activity deals with very simple reach and touch exercises. The second activity uses a touch screen and is designed for recovering stroke patients during the early stages of recovery.

Grip Force and Wrist Rotation Game

The Grip Force and Wrist Rotation Game is designed to engage a client while having the person move through a series of therapeutic exercises targeting not only increased force or torque production, but more importantly controlled force or torque modulation. The program has three modules; a range-of-motion assessment module, a game module, and a therapist data and performance review module. User performance data is collected from the assessment and gaming modules and a database management module computes summary statistics that the therapist can view with the performance review module.

Before beginning therapy and at regular intervals during therapy, the client will use the test screen to measure the range of motion that they can produce. This module displays specific targets for the client to attempt to reach. As one is reached another appears. These give a consistent measure that can be used for comparison throughout treatment. Figure 23.2 shows screen shots of the range-of-motion assessment module.

For the game, the client uses our hardware to move a "bucket" across the screen from side to side to catch apples. The game keeps scores, apples caught, so that the client can see if they are improving. The game also allows the speed to be adjusted to better suit patients with slower reaction times at the beginning of treatment. Figures 23.2 and 23.3 show screen shots of this activity.

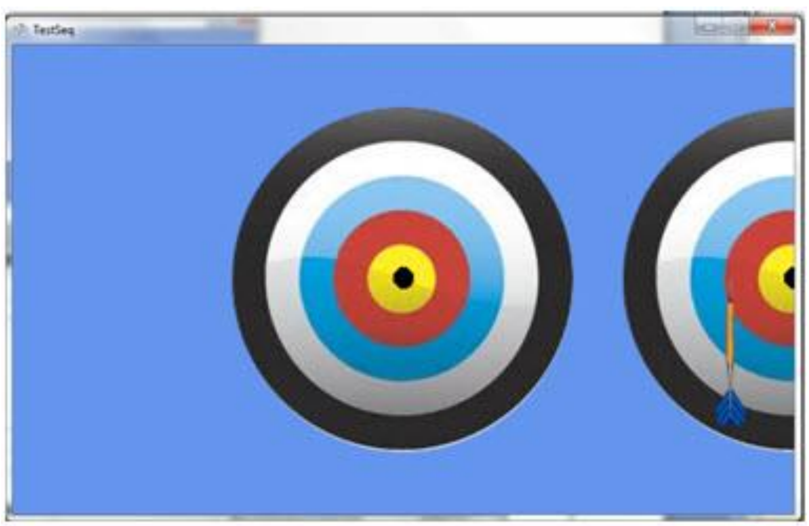

Fig. 23.2. Screen shot of the range-of-motion assessment module.

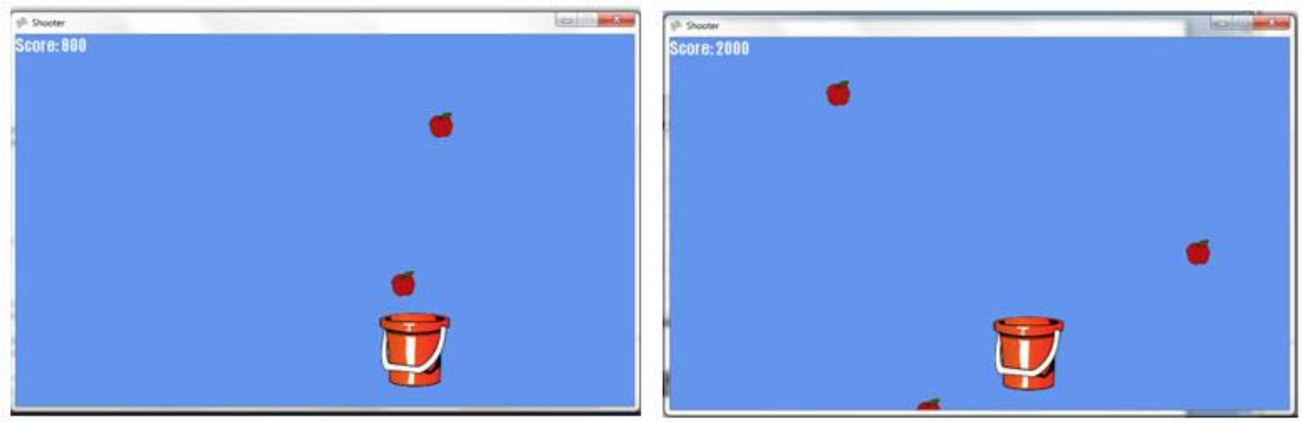

Fig. 23.3. A screen shot of falling apples and the bucket used to catch the apples. Apples fall randomly across the screen and the user must modulate/control the squeezing (grip) force to control bucket speed and placement.

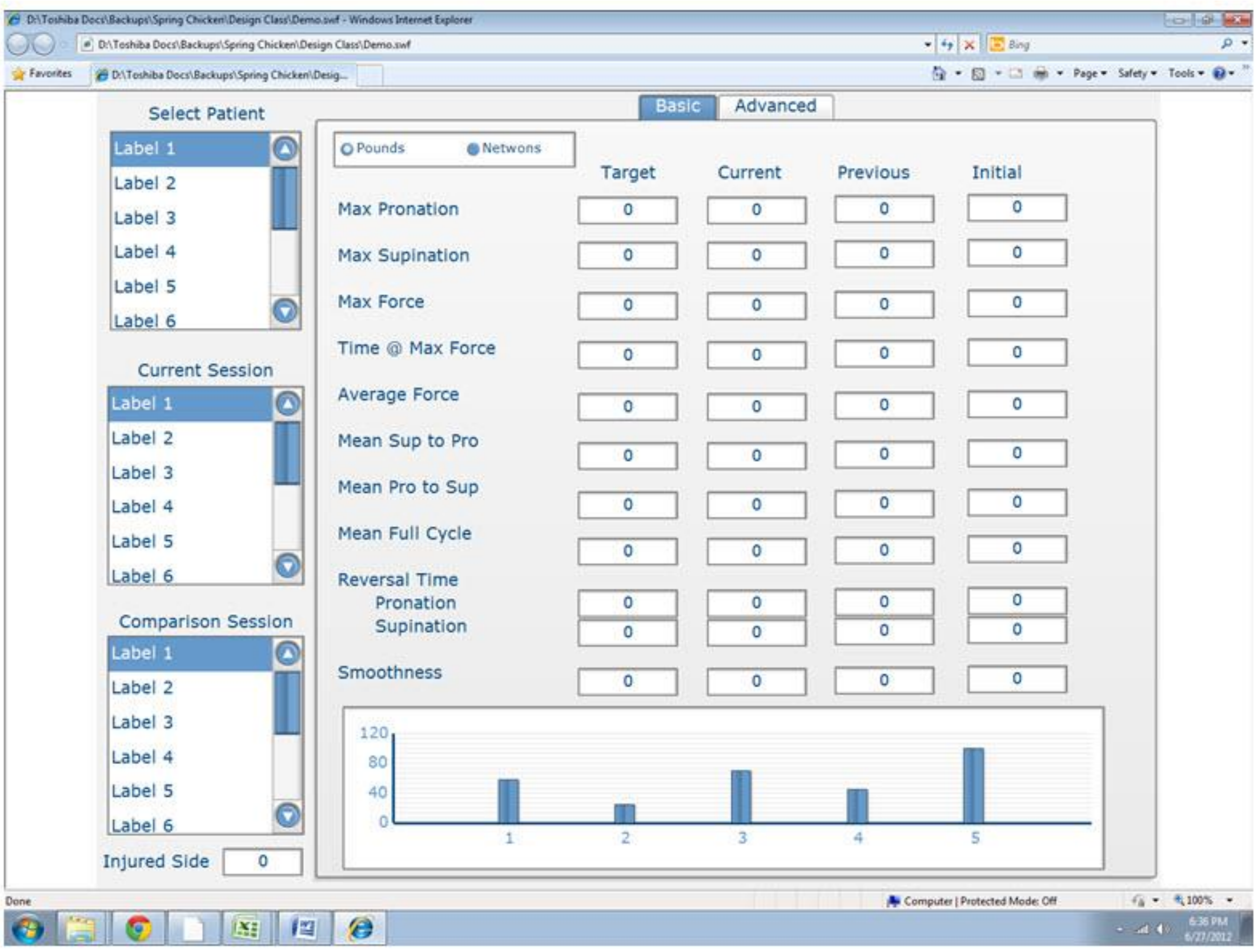

Fig. 23.4. This is a screen shot of the client performance review module.

Figure 23.4. Shows an image of the client performance review module. The raw data is stored to an Excel file and is available for more detailed analysis as deemed necessary.

Bubble Game

The Bubble Game is the second therapeutic activity program. The client is seated with her hand on a home switch. The home switch is placed so that the person's arm and hand rest naturally. A "bubble" is randomly placed on the touch screen and the client must reach out and pop, touch, the bubble image. Then the client must return their hand to the home switch. This patterned movement, home-touch image-home, is called a cycle. The program records the time an image appears on the touch screen, the time the client leaves the home switch, the time the touch screen is touched, whether the touch is a "hit" (pops the bubble), or a "miss" (does not pop the bubble), and lastly the time the client replaces her hand on the home switch. Figure 23.5 shows the setup screen. A client's name and ID are entered and then a "bubble size" is specified along with a case number which specifies the number of bubbles to be presented. Figure 23.6 shows a user performance summary where 22 bubbles were presented the client "popped" 20 of these and the entire session took 4.83 minutes. Cycle time and performance data are stored to an Excel spread sheet. The summary performance shown in the text box is derived from the saved data. The image in the lower left/center of the screen shot is the "bubble." The Bubble Game is programmed in C++ and is displayed on a touch screen. The touch screen can be mounted to the generic end-effector bracket discussed previously, or to a table top mounted flexible screen mount. A table top flexible screen mount has been ordered and the Bubble Game will be utilized with xAr system when it arrives.

Fig. 23.5. The setup screen. The therapist would configure the parameters of the therapeutic activity.

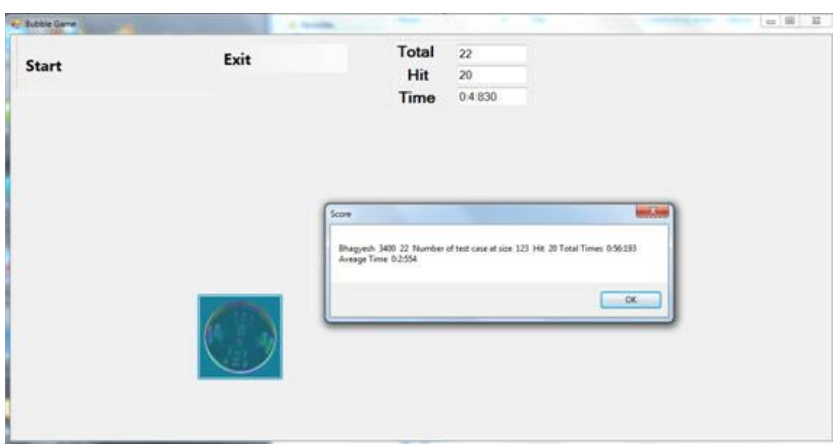

Fig. 23.6. The performance summary screen.

xAr CREFORM Frame

The xAr is an exoskeleton arm that attaches to one's arm and provides dynamic support throughout the arm's natural range of motion (http://www.equipoisinc.com/products/xAr/). The unit was designed to provide ergonomic relief for repetitive tasks involving the arm by removing the effects of gravity. The Enabling Technologies Laboratory and the ARM Clinic are partnering with Equipois, the manufacturer of the xAr to explore its efficacy in rehabilitation settings. The xAr can be used independently or in combination with the rehab robotic systems previously described.

The xAr needs to be supported by a chair or workstation and mounted so that the users can experience a full range of arm movement. The ARM Clinic users are seated in wheelchairs and it is not possible to affix the xAr to each wheelchair for the duration of the evaluations. Hence an external frame was designed to serve as a mounting platform for the xAr arms (right and left arm units). The frame was constructed from Creform, an agile systems technology, and allows easy wheelchair access and placements of the right and left xAr units so as to ensure an unimpeded full range-of-motion. Figure 23.7 shows an illustration of the xAr on a CAD human figure. Figure 23.8 shows an ARM Clinic client using the xAr from his wheelchair positioned in the Creform frame.

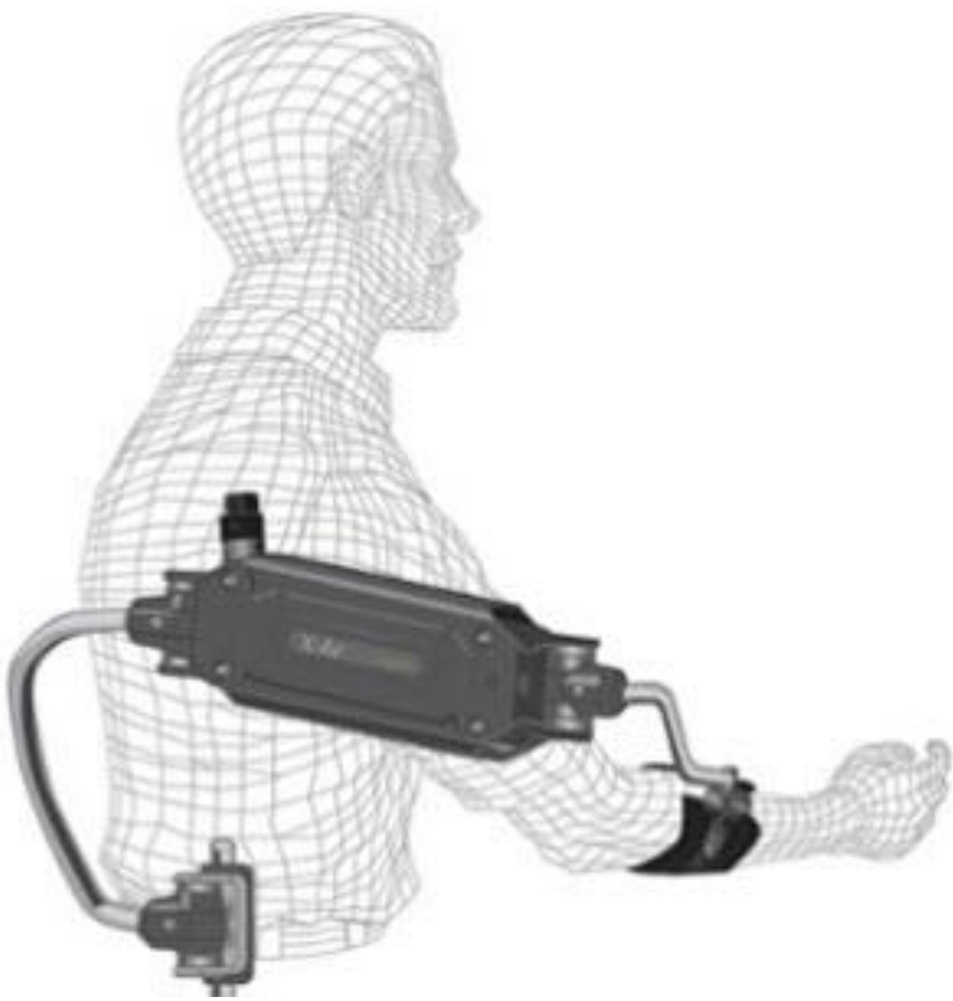

Fig. 23.7. The xAr shown on a CAD Model.

Fig. 23.8. A client using the xAr devices while sitting in his wheelchair in the Creform frame.

The CREFORM frame has a hinged rear door so that when opened a wheelchair can be rolled forward into the frame and aligned for the xAr units. CREFORM is a pipe & joint system and has a range of adjustable fittings making it ideal for an evaluation system. A wide range of xAr positioning options afforded by the frame allow therapists to very quickly make positional changes based on user and wheelchair size.

CONCLUSIONS

The ARM Clinic has started its second year of operation. The therapeutic exercise systems being developed by the Enabling Technologies Laboratory student design program enables the ARM Clinic to better serve its target population with limited staff. Moreover, these systems are being designed to function with rehabilitation robotic devices so as to provide therapeutic protocols consistent with established and evolving neuroplasticity research results.

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INTELLISTREETS®: HOW CAN THIS NEW PRODUCT SERVE PEOPLE WITH DISABILITIES?

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INTRODUCTION

IntelliStreets® new intelligent outdoor street lighting system developed by Illuminating Concepts, a Michigan based company in Farmington Hills to provide urban designers a unique and powerful platform for the delivery of accessibility features within a universal design context. The system can take advantage of built in microprocessors and a wireless communication network to not only control LED lighting, but also address way finding, accessibility and safety concerns. IntelliStreets® is a network of inter-communicating LED streetlights while providing cost-efficient, urban lighting.

Key elements of the IntelliStreets (IS) system are its process control microprocessor and wireless dual band mesh transceivers. Like all Smart Grid systems, the IS system uses long lasting LED's to provide illumination. The advantages of LED luminaries include improved night visibility, instant on, less hazardous (no mercury or metal), long life span, cost-efficient use, and reduced maintenance costs. The brightness of the light can be programmed and controlled for high intensity lightning during dark peak hours of pedestrian and vehicular traffic.

SUMMARY OF IMPACT

IntelliStreets® is one example of new technologies that are embodiments of ambient intelligence. While much speculation has been given to the potential benefits that can be derived from such technologies for people with disabilities little if any practical work has emerged. This project focused on outdoor wayfinding and is part of a broader Enabling Technologies Laboratory R&D effort to identify specific outdoor wayfinding and mobility issues and pursue solutions. The results of this project derive from a series of meetings and discussions with individuals living with specific disabilities and professional service providers. The project goal was to not just identify problems, but more importantly to imagine and hypothesize products that can add-value to IntelliStreets by utilizing universal design strategies to address the identified problems. These product ideas will then be the basis for future student design projects that could very well lead to marketable products.

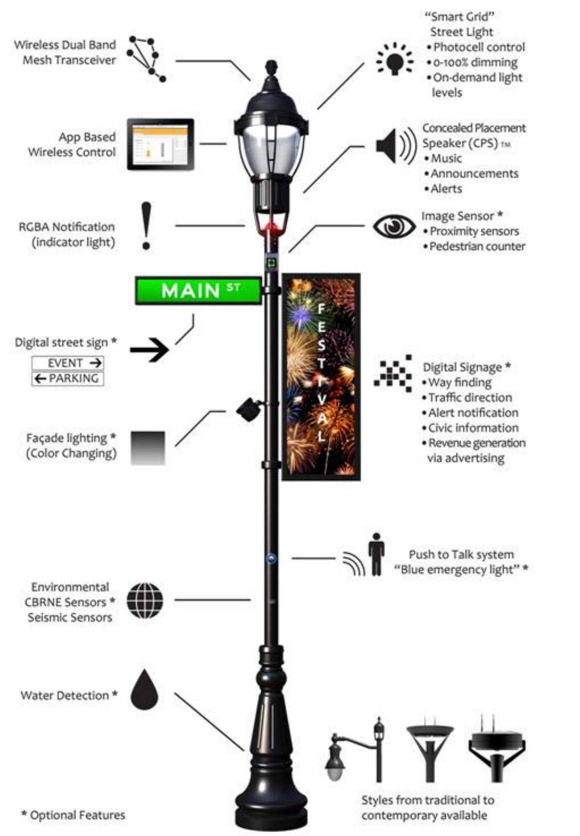

Fig. 23.9. The IntelliStreet® pole and available features.

TECHNICAL DESCRIPTION

The hypothesized products will not replace GPS based wayfinding but complement that technology by using methods and strategies for providing data and information about the local, nearby environment. For example, are local sidewalks under repair or navigable by wheelchairs? Are there ADA compliant accessible public toilets nearby and where? Are local roads under repair and where? Are any handicapped parking places nearby, are they available and where are they?

The imagined products focus on streetlight pole location issues and Mobile Apps for smart phones wherein there is a communication linkage between the smart phone and IntelliStreet® system to facilitate outdoor wayfinding. Three pole locations were considered: poles at crossing intersections with no traffic lights, poles on sidewalks, and poles in or near parking lots. Specific functionalities were presented for all three pole locations but common to all were specific pole finding methods such as pole sensing by use of an RFID tag identifying a potential user. An RFID tag reader could be part of the pole's instrumentation. Using the speaker system a tone could localize the pole and user interface located on the pole. The user interface would then be the gateway for a variety information exchange.

Two Mobile Apps were imagined. IntelliStreets Mobile App for accessibility version will include all VR commands from sidewalk and crossing intersection poles, plus extra commands. This would be free or low cost. IntelliStreets Mobile App Pro Version a mobile application that can be purchased for a low cost of $1.99 or $2.99 which could generate profit. The app will have menu buttons and will also support VR button. This version could also provide most features provided in the accessibility version,

Fig. 23.10. Range of features.

with addition of social network access, entertainment, and parking allocation for non-handicap space. This feature is especially important for people who visit the downtown more often and experience hard time finding a parking spot. The smart phone apps could also allow users to control street light illumination in lightly traveled areas by offering a "light-on-demand" feature similar to the

Dial4Light system used in Germany. The imagined products which have resulted from this project provide solutions to outdoor wayfinding issues as expressed by project collaborators. These products give expression as to how IntelliStreets® and other ambient intelligent infrastructure can in fact utilize universal design strategies to address accessibility concerns.

CHAPTER 24
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