CHAPTER 7
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BALANCE TRAINING BICYCLE

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Client Coordinator: J.J. Mowder-Tinney, Nazareth College Physical Therapy Clinic
Supervising Professors: Dr. Elizabeth DeBartolo, Dr. Matthew Marshall
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INTRODUCTION

In the absence of balance training tools that provide a safe, low risk of injury to the patient, the design team was given the challenge of creating a Balance Training Bicycle to be used by physical therapy patients at the Nazareth College Physical Therapy Clinic. The bicycle design simulates the instability of a freestanding bicycle without the risks associated with actual bike riding. Patients in need of balance training are those who have had strokes, or those who have other neurological conditions that cause an imbalance in strength between the left and right sides of their bodies. The concept behind the bicycle design is to serve as an intermediate balance training tool that is more challenging than a traditional stationary exercise bike, but less challenging than a traditional free standing bicycle.

SUMMARY OF IMPACT

A bicycle frame was designed to allow for easy entry

Fig. 7.1. Completed prototype.

and exit, as well as to provide ride-ability characteristics that mimic that of a traditional bicycle. To meet project requirements, a low cross-member is coupled with a vertical post that positions the handlebars in front of the seating position that is located by two angled posts. The cross-member is supported by two pillow-block bearings that allow for frictionless rotation about the center axis. The rotation about the axis provides the side-to-side tilting capability that mimics the motion experienced on a traditional bicycle. Variable tilt resistance is achieved through the use of a spring cartridge with adjustable preload controlled by an electric winch. The clinic coordinator is excited to begin using the device with her patients and after riding the bike herself, she has determined that it will be beneficial for seated balance training for many more of her clients who would not normally train on an exercise bicycle.

TECHNICAL DESCRIPTION

The finished prototype is shown in Figure 7.1. The bicycle can be locked in the upright position by engaging the spring loaded pin lock at the rear of the bike. There are five spring cartridges corresponding to five different weight classes. Spring compression and tilt level are controlled by shortening or lengthening the cable with the electric winch. The handlebars can be adjusted to accommodate various patient sizes using the rotary hinge. The seat height is also adjustable. Pedal resistance is controlled by varying the amount of friction applied through the resistance knob. There are two wheels located at the front of the bike which allow provide a “wheel barrow” style portability feature for easy transportation. The feedback display provides an indicator of the patient’s degree of tilt to both the patient and the physical therapist. As the angle of the bicycle shifts away from upright, the LED array indicates the degree of tilt with green (upright), yellow (tilting but still stable), and red (unstable) LEDs. An audio feedback system begins to beep when the tilt angle is in the yellow LED range, and beeps with increasing speed in the red LED range.

The total cost of the project was $1,865.74 ($2,086.35 including donations).

More information is available at http://edge.rit.edu/content/P08001/public/Home.

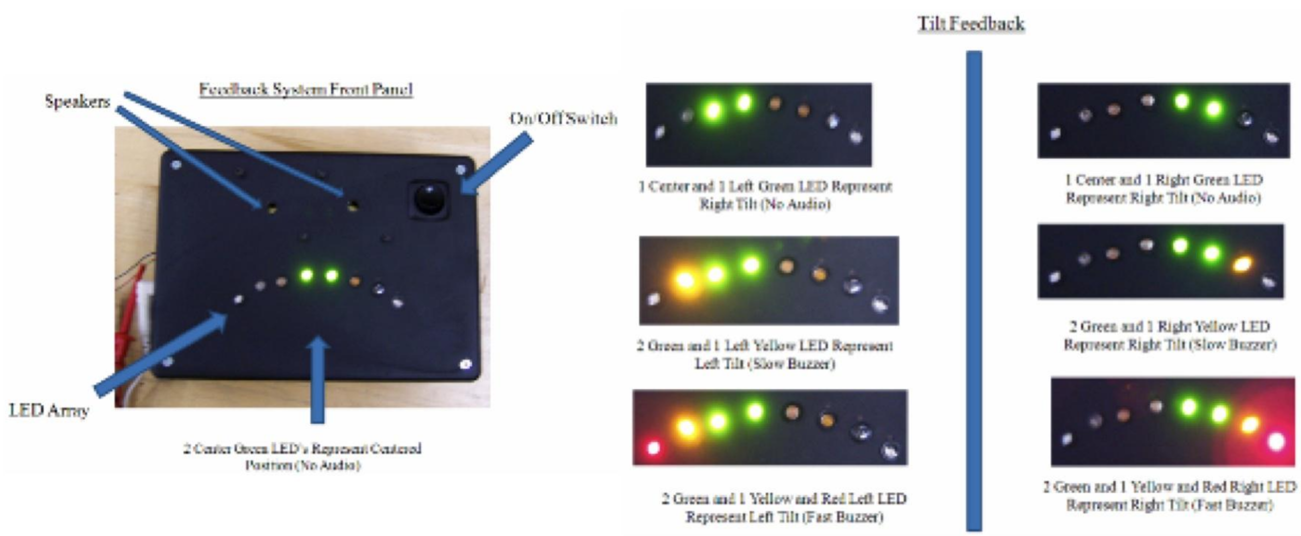

Fig. 7.2. Feedback display.

AUTOMATED PARALLEL BARS

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INTRODUCTION

The physical therapy clinic at Nazareth College frequently uses parallel bars with adjustable height to aid patients in relearning to walk. The previous system was difficult to adjust, consisting of six posts, each with a hole-and-pin system. Due to the length of the bars, the current system is very difficult to properly align. The difficulty lies in accurately matching the number of holes exposed and results in the parallel bars not being parallel, which can make a therapy session difficult for the patient. Additionally, if a therapist positions a patient on the bars and discovers that the height needs a slight readjustment, the patient is required to sit back down. Some patients have such difficulty standing up a second time, it often results in the session being aborted.

SUMMARY OF IMPACT

The redesigned system replaced the current pin and post system with two sets of three power screws, connected in series by a drive shaft, and powered by a stand-alone hand crank. Some strengths of this system include usability, safety, appearance and the ability to revert to the previous system. Both sides of the parallel bars can be easily adjusted from one central location, at the hand crank, rather than walking around to adjust the six individual posts. The system is safe; a drive shaft safety cover protects the patient and therapist against the rotating drive shaft and pinch points. From an aesthetic perspective, the system is finished with a durable, neutral grey powder coating. Lastly, should the customer be unsatisfied or the design does not function as expected over time, the system can be removed and the previous system can be reinstalled. The clinic director is excited to begin using the device with the start of her new academic year this September, and has already identified other ways she can use the new parallel bar system, such as using the drive shaft cover to help with stretching exercises.

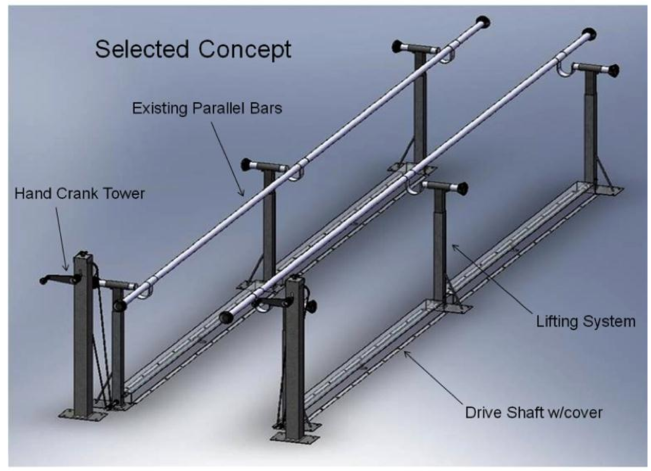

Fig. 7.3. Selected concept.

Fig. 7.4. Actual installed system.

TECHNICAL DESCRIPTION

The selected concept is shown in Figure 7.3 and the actual installed system is shown in Figure 7.4. The two key subsystems are a lifting system and a hand crank tower.

The lifting subsystem consists of three posts tied in series by a single low-profile drive shaft that run along the floor. The drive shaft is protected by a cover so the system is safe for both the physical therapist and the patients. A 1:1 perpendicular miter gears transmits rotation from the drive shaft to vertical motion of an ACME threaded rod in each of the posts. This 5/8-8 ACME Rod supports vertical loads and transmits weight to outer post. An ACME nut is welded to the inner post, and rides up and down rotating the threaded rod (Figure 7.5).

A hand crank tower subsystem was developed with a 4:1 gear ratio for the belt. This results in ½ inch adjustment per revolution of the hand crank. The hand crank was ergonomically located at the height of 36 inches, which is within the elbow to hip height range. Based on test results the system is easy to adjust, with the torque requirements well below the engineering specification. Lastly, the handle for the hand crank is removable to prevent incidental adjustment. See Figure 7.6, which shows the details of the hand crank tower subsystem.

Finally, the user has been left with a user's manual as well as a detailed maintenance guide that includes instructions on how to revert to the previous system should the user be dissatisfied with the new system.

The total cost of the project was approximately $1,500.

More information is available at https://edge.rit.edu/content/P08002/public/Home

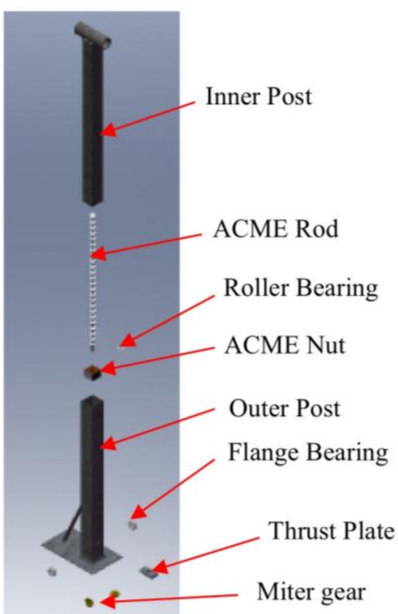

Fig. 7.5. Lifting system.

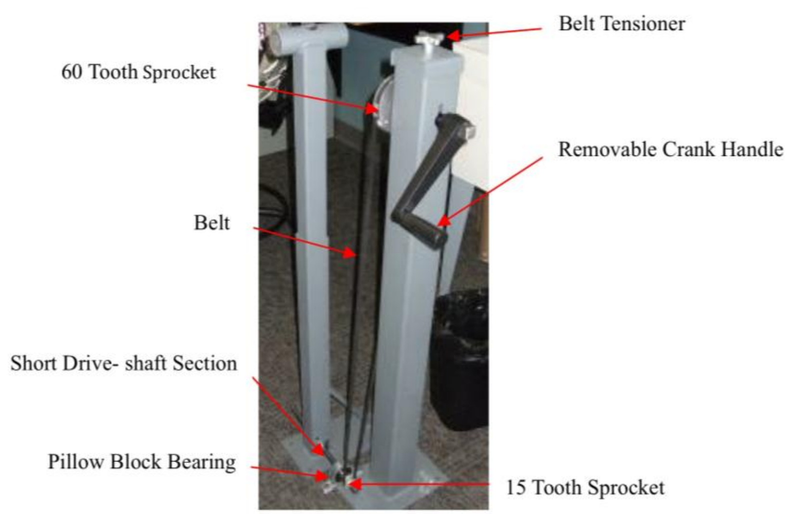

Fig. 7.6. Hand crank tower.

PORTABLE OBSTACLE COURSE

Mechanical Engineering Designers: Shadle Stewart (team leader), Jared Berman
Industrial Engineering Designer: Nicolette McGeorge
Electrical Engineering Designer: Allison Hill
Computer Engineering Designer: Samir Mian
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INTRODUCTION

The physical therapy clinic at Nazareth College works with many individuals who have had strokes and are relearning to perform everyday activities. An important part of their training is learning how to navigate an obstacle course consisting of typical items that might be found in or around a home environment. The physical therapists would like to have a standardized course that can be dismantled and stored when not in use and later reassembled to a prior setting in order to directly track patient progress.

SUMMARY OF IMPACT

The finished project yielded eight walking surfaces than can be assembled to create a walking path approximately 16 ft. long, along with nineteen total obstacles (Figure 7.7). A storage cart for the surface pieces, along with a storage bin for the obstacles was also provided. All surface pieces contain embedded circuitry that includes through-put boards, micro switches and wiring in preparation for future use with a microcontroller and printer to automatically print the course layout for the therapist's records. In the meantime, copies of a tracking sheet, similar to the one the printer will provide, are included with

Fig. 7.7. Sample course setup.

Fig. 7.8. Surface piece layers.

the product. The obstacle course and cart are fully functional without the automated tracking system and can still be used for patient training sessions. In an upcoming class on Embedded Microcontrollers, we will complete the design and implementation of the microcontroller and printer interface. The clinic coordinator, who has been searching for ways to give her patients concrete information about their improvement from session to session, is looking forward to using the new course when the clinic re-opens in the fall.

TECHNICAL DESCRIPTION

Eight surface pieces were constructed with surfaces including light hardwood, dark hardwood, low carpet, high carpet, gym mat, simulated concrete, simulated ice, and simulated gravel. Each surface has five fixed mounting points where obstacles can be placed, and the tracking system wiring embedded within each surface connects these five points with a circuit board and to the neighboring surfaces. Each piece is a laminate of several different layers (Figure 7.8) including foam, plywood, and particleboard. Nineteen obstacles are included with the system, including four rugs, two curbs, a heater vent, a threshold, four shoes, two pillows, two bundles of cables, two stuffed animals, and a stack of books. Each obstacle is equipped with a standard peg (Figure 7.9) that fits into one of the five holes on any given surface piece. When an obstacle peg is inserted into a hole, it depresses a micro switch that records the presence of an obstacle at that location. Although the system is capable of handling four surfaces, each with up to five

Fig. 7.9. Obstacle peg and pillow obstacle with peg attached.

Fig. 7.10. Embedded wiring and circuit board.

obstacles, the circuits have been designed for single pin output (Figure 7.10 and Figure 7.11).

The Storage System consists of a cart that holds all eight surface pieces, and a storage bin to hold the obstacles. The cart allows for easy setup by storing the pieces with the handles on top for easy access. This allows the physical therapist to move the cart close to the setup area to minimize carrying distance and setup time.

The total cost of the project was $1,730.

More information is available at https://edge.rit.edu/content/P08003/public/Home

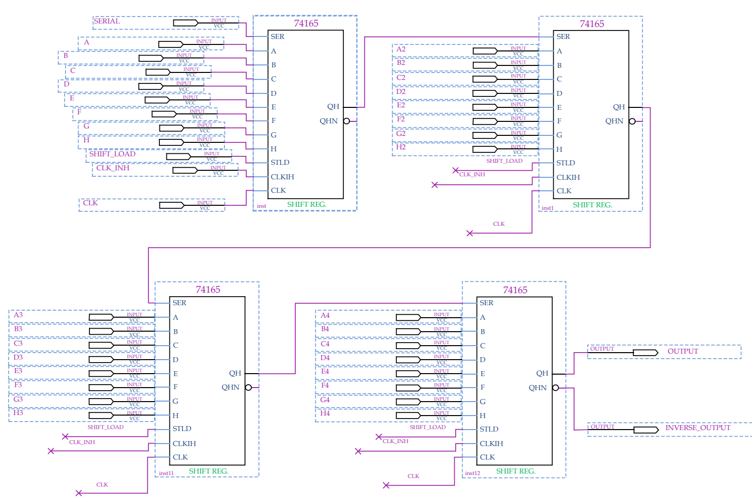

Fig. 7.11. Four serial shift registers chained together to produce single pin output.

ADAPTABLE BOCCE BALL LAUNCHER

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INTRODUCTION

The New York Special Olympics (N.Y.S.O.) organization wanted to add bocce ball as a sport for their athletes to participate in, but many of the athletes were unable to produce the force required to roll a bocce ball 60 feet. A simple non-intrusive assistive device was needed to enable more athletes to fully participate in the sport. The customer requested that the device not take away the skill level that comes with strategically placing objects, as well as keeping the final device very simple, with no impact assistance.

SUMMARY OF IMPACT

The need for an assistive device led to the development of the adaptable bocce ball launcher, which strategically rolls the balls down a ramp without taking the need for skill development out of the game. This device is essentially a portable ramp on top of a locking swivel base, resulting in providing a means for a greater range of N.Y.S.O. athletes to participate. The device will allow many more athletes to participate in indoor bocce played on a variety of surfaces for both competitive and social interaction.

TECHNICAL DESCRIPTION

The ramp design chosen was a straight V-channel section with a curvature at the end. Several different profiles were explored using simulation, but this was found to be the optimum option based on manufacturing and velocity attained. Exit velocity and rolling distance are determined by placement of the ball on the ramp. Releasing the ball at the very top of the ramp gives the ball the greatest amount of velocity and force to go the maximum distance, or have the most power to strike other balls. The curvature at the end of the ramp allows for a minimal loss of energy upon the balls impact with the court surface. The V-channel allows for both the pallina and bocce ball to be rolled on the same ramp, with only two contact points for each ball.

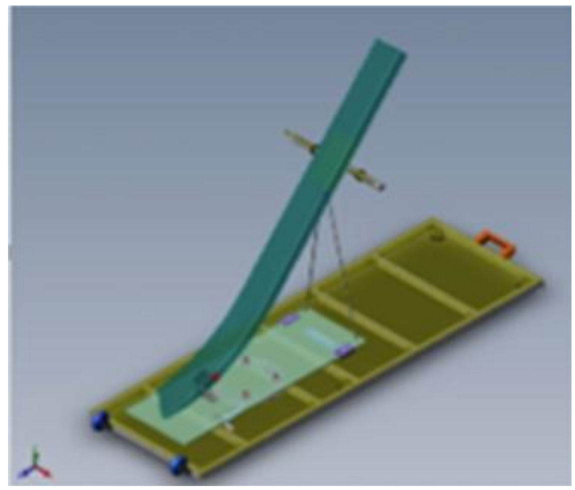

Fig. 7.12. Ramp deployed for play.

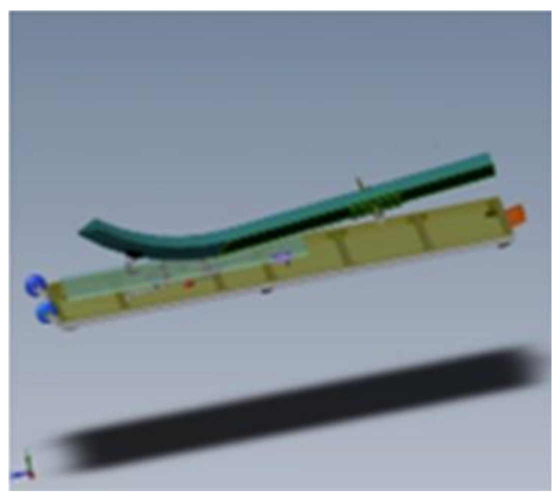

Fig. 7.13. Ramp folded for storage.

The ramp has two positions: extended for use in play (Figure 7.12) or collapsed for storage and transportation (Figure 7.13). The ramp is supported at two locations when extended: the front pivot hinge and the back legs. The top of the device can be reached by 95% of wheelchair users. When collapsed, the legs are pivoted underneath the ramp and the ramp rests on the base. When the ramp is inclined, the legs naturally swing down into place and the user inserts them into their locating holes.

The pivot hinge and legs are mounted onto a platform made of polyvinyl chloride (PVC) that rests on top of a swivel. This piece allows the ramp to rotate 15 degrees in either direction until it hits a stop, enabling a user to aim at any position on the court from either side of the ramp. The swivel is mounted onto the top of the base with a brake system. The base is the footprint of the ramp's length and the width of the PVC platform. These dimensions will safely keep the users far enough away from the rotation of the swivel.

The base has two wheels located on the front at an angle that allows them to only be engaged when the user picks the ramp up from the back with a mounted center handle. These wheels allow the user to easily position or reposition the device in a desired location. When the ramp is ready for game play the wheels are disengaged and do not interfere with the path of the pallina or the bocce balls. Figure 7.14 shows the completed device.

The handlebar system consists of an angled piece of steel plate, contoured to the underside of the ramp and held in place with structural adhesive. This plate has two aluminum rods welded to it creating easily gripped handles. These handles are covered with a grip to provide a safe interface with the user. The handles are the main points of contact for users aiming the ramp from either the left or right side, accommodating users that are either left or right handed. The height of the handles is conveniently located to allow comfort for users that may be seated. Each handle has a lever connected to the braking system.

The brake allows the user to lock the device in place during their turns. This prevents accidental movement of the ramp's position when the athlete rolls the bocce balls. Also, if a volunteer is holding the brake in place until the athlete's turn is finished, shifting the ramp after each turn may prevent "memory" of aiming the ramp in the same location

Fig. 7.14. Final constructed device.

automatically. When a user squeezes the handle the brake is engaged against the swivel, locking it firmly in place. Once the user has finished their turn, the brake lever is released and the swivel is free for movement.

A protective cover was designed to provide basic protection for the device while it is being transported or stored. The composition of the cover consists of the same 80/20 extruded aluminum as the base, giving it an aesthetically pleasing look. When placed over the ramp and locked in place with latches the device is plain shaped and can be easily stacked.

Finally, the user has been left with a detailed user's manual that includes maintenance, operation and future manufacturing instructions, as well as a reusable mold for duplication purposes.

The total cost of the project was $1,422.98.

More information is available at http://edge.rit.edu/content/P08004/public/Home.

MOUNTING SYSTEM AND USER INTERFACE FOR ELECTRONIC COMMUNICATION BOARD

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Industrial Designers: Amy Koster and Rachel Lepkowski
Client Coordinator: Lisa Drewski, ARC of Monroe County
Supervising Professors: Dr. Daniel Phillips and Dr. Elizabeth DeBartolo
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INTRODUCTION

The ARC of Monroe County works with an individual who is able to understand when others speak, but who cannot communicate with others beyond some very basic sign language. She has used a notebook with Mayer Johnson symbols to communicate in the past, but frequently gets frustrated with the book and does not use it. A prior senior design team created an electronic communication board that would speak for her, and this year the design was refined, and a system to mount the board to the user's wheelchair was created.

SUMMARY OF IMPACT

The new communication board is smaller, designed to be visually appealing to the customer, and can be securely fastened to the individual's wheelchair. The first time the customer saw the new design and user interface during the demonstration session, she

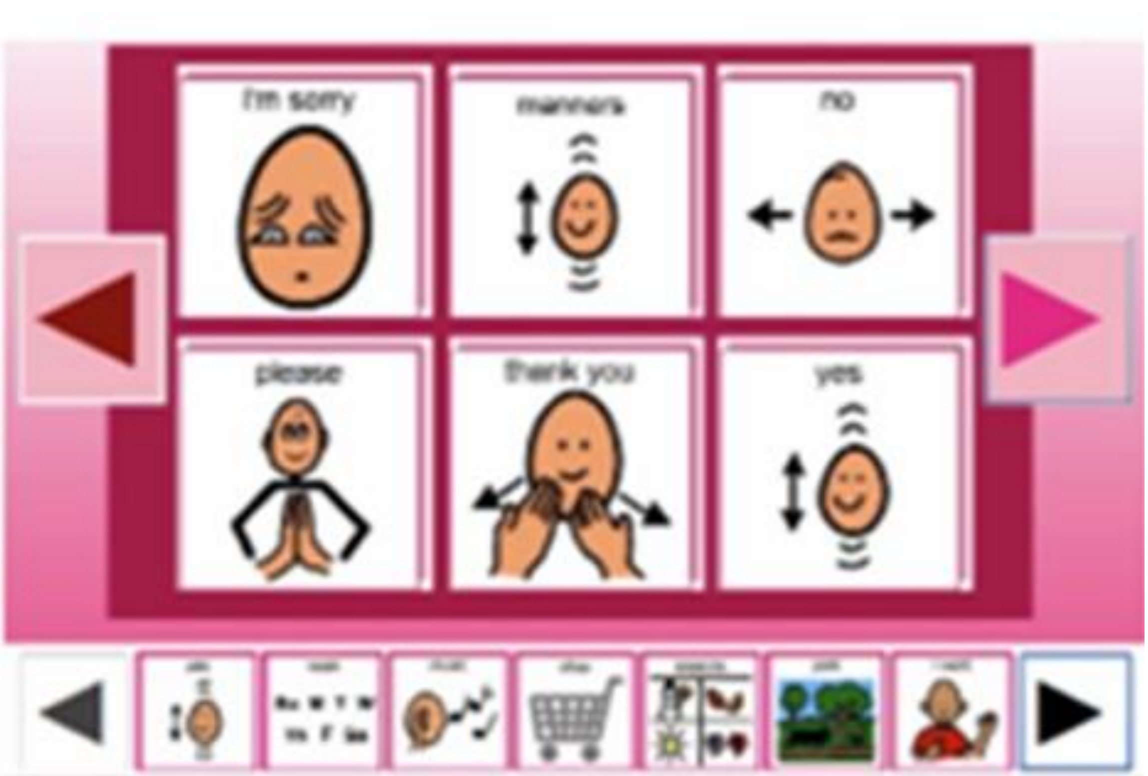

Fig. 7.15. Screenshot of the communication board graphical user interface.

repeatedly pressed the symbol that speaks the word "excited".

TECHNICAL DESCRIPTION

Based on the results of the previous project, the complex nature of designing a robust custom embedded computing system on a limited budget, and the sensitivity to the expectations of the individual and her caregivers, it was decided to approach the project in a phased manner. The system consists of a robust touch-based display, with sound generation mounted and an adjustable boom assembly that is securely and easily attached to the individual's wheel chair. The rechargeable battery based power supply and embedded processor are connected to the display via a multiple conductor cable and located on the wheel chair in the space under the wheelchair seat. In this phase of the project, the deliverables are focused on the display unit, the actual embedded software application (shown in Figure 7.15) and the boom assembly. The application was developed on a Viewsonic V212 wireless tablet running Windows CE. This provided a prototypical embedded development platform that closely resembles the intended system, including an integrated touch screen. This enabled an iterative software development cycle that is quickly modified and evaluated. The software is developed using Visual Studio 2005 and the C# programming language, allowing rapid application generation that is easily be ported to either an embedded operating system (Windows CE) for the target hardware or a conventional operating system (Windows XP) for evaluation on standard desktop or laptop platforms. The development on the Viewsonic V212 wireless tablet facilitated early evaluation of the touch interface by the individual, while an appropriate LCD touch screen was ordered and integrated into the application software running on a laptop computer running Windows XP, which acted as a "stand-in" for the embedded processor that will ultimately be integrated into the system. In other words, the LCD touch screen for the project acted as the user interface for the application that was running on the laptop computer, providing display, sound, and user input. This method of software development allowed simultaneous and parallel design and implementation of the enclosure for the LCD touch screen as well as the positioning assembly to occur.

Fig. 7.16. Final manufactured enclosure.

The interface enclosure, which is designed to hold a Caltron Industries 12.1" LCD touch screen (12V power, 800x600 pixels) that uses thermoformed ABS plastic (Figure 7.16). The thermoforming process enabled a case design that incorporates smooth and rounded features that results in an attractive and sleek appearance. The case is designed to be aesthetically appealing to the customer, using paint in the customer's favorite colors to increase her motivation to use the device. A pair of USB powered amplified speakers are mounted behind the LCD touch screen assembly in the enclosure (Figure 7.17). This enables the incorporation of a degree of fluid protection into the enclosure as the speaker baffles are rear facing and away from the most probable direction of accidental spills and fluid exposure. It also directs the sound from the device in the direction of the person(s) who would be facing the individual using the device.

The case containing the touch screen running the GUI is attached to the customer's wheelchair using a custom-designed mounting arm (Figure 7.17). The arm is made from 7/8" OD 4130 steel tubing with a 0.12" wall thickness and is designed to meet strength requirements, as well as to prevent excessive deflection under typical loading of both the device itself and the forces due to the individual interacting with the device. The mounting arm is connected to the individual's wheel chair using a custom designed adjustable and removable mounting clamp that provides adjustments for positioning of the overall system relative to the wheel chair. There is an adjustable angle elbow that allows positioning of the touch screen interface relative to the individual, and then an adjustable LCD mount that allows for optimal orientation of the touch screen interface. The touch screen interface is affixed to the mounting arm using a standard LCD quick connect VGA computer display adapter.

The individual commonly uses a tray attached to her wheel chair and the touch screen interface is meant to be able to rest on that tray at eye level and within easy reach. The bottom of the enclosure incorporates rubber "feet" meant to rest on the tray and provide an additional degree of stability when the individual is interacting with the touch display. Cabling between the display and the embedded processor and power supply (located under the seat of the wheel chair) will be implemented via a flexible cable enclosure attached to the mounting arm. The next phase of development will determine the optimal mounting system for the embedded processor and power supply.

The total cost of the project was $1,800.

More information is available at https://edge.rit.edu/content/P08005/public/Home

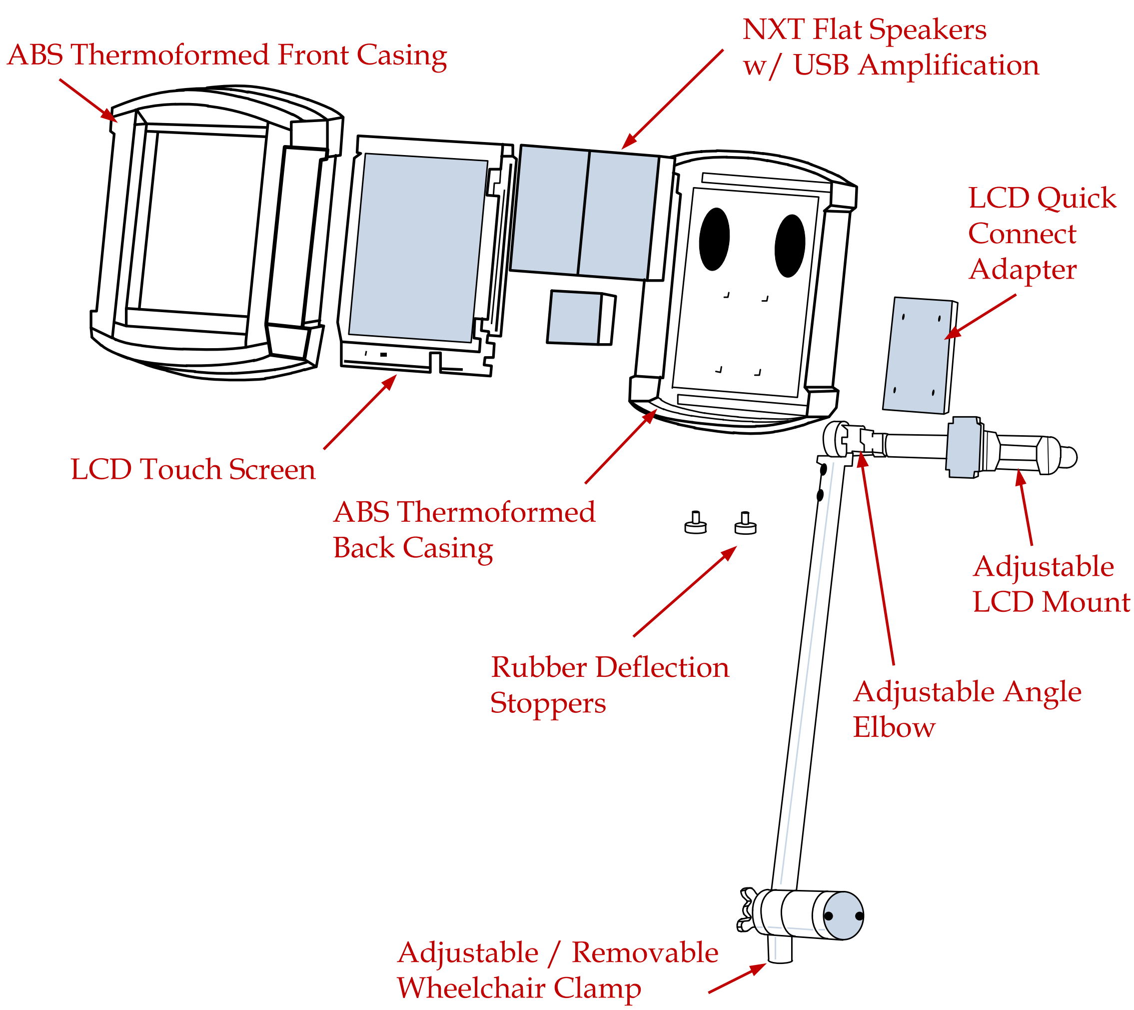

Fig. 7.17. Exploded view of the system allowing the communication board to mount to the user's wheelchair.

MOTION TRACKING SYSTEM

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Electrical Engineering Designers: Wade Daugherty, Brian Leigh, and Josemaria Mora (team leader)
Mechanical Engineering Designer: Jennifer Mallory
Client Coordinator: JJ. Mowder-Tinney, Nazareth College Physical Therapy Clinic
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INTRODUCTION

As a part of a typical physical therapy regime for patients recovering from strokes, a gait assessment is performed. Many of the clinic's clients have an irregular gait, and the clinic currently has several devices that measure such features as balance and weight distribution. However, they do not have a method for measuring the hip, knee, and ankle joint angles during walking. The clinic only has means of making a qualitative assessment of the patient's motion and progression, lending to an incomplete evaluation of each patient. If the clinic did want to obtain the measurements of the joint angles, they can only do so by using a goniometer while the patient is not moving. This measurement requires two therapists, and is both inefficient and inaccurate as it does not provide an accurate assessment of the patient's dynamic progress.

SUMMARY OF IMPACT

The resulting device is based on gyroscope output. Gyroscopes are enclosed and attached using an electrode-snap system to pre-identified anatomical reference points (Figure 7.18). Angular velocity data is sent from each gyroscope to a microcontroller, and then transmitted to a computer via Bluetooth. Angular displacement for the hip, knee, and ankle joints is then calculated and displayed on the computer. The data is stored for comparison in future therapy sessions. In the future, this system may be the basis for telemedicine work that the clinic is considering to enable them to work with patients who would otherwise be unable to undergo physical therapy.

TECHNICAL DESCRIPTION

The Motion Tracking System is based on data collected through eight Analog Devices ADXRS300 gyroscopes. The gyroscopes are enclosed in small

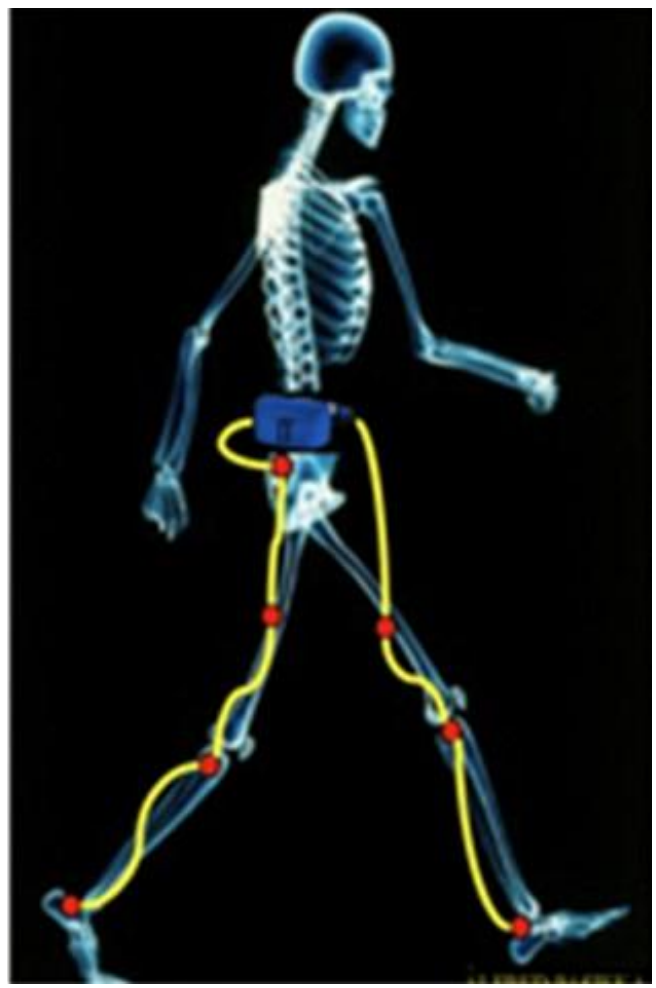

Fig. 7.18. Schematic showing locations of gyroscopes.

plastic cases that are attached to the patient's skin using ECG electrodes. Data is transmitted to a MSP430 microcontroller worn on the patient's waist belt. Using a BlueSMiRF Bluetooth wireless modem, raw angular velocity data is transmitted to a laptop computer where it is processed, displayed, and saved using a Java script written by the design team.

The raw angular velocity data is integrated to obtain angular displacement. A sample of the resulting user interface is shown in Figure 7.19.

As part of the team's testing procedures, data are collected for normal walking profiles, as well as for irregular walking to simulate the way a typical patient might walk, without flexing the knee. Evaluation of the device indicates that the system is functional, as shown in Figure 7.20. The system can detect different gait patterns as shown in Figure 7.21. For the hip angle, the clinic staff is only interested in documenting whether flexion occurred, and not the actual range of flexion. For the knee and ankle, the actual degree of flexion is needed.

Some difficulties were encountered with the design. For unexplained reasons, the system was unable to accurately collect and display more than one cycle of data without the error increasing drastically. Additionally, the data transfer rate between the microcontroller and laptop was slower than

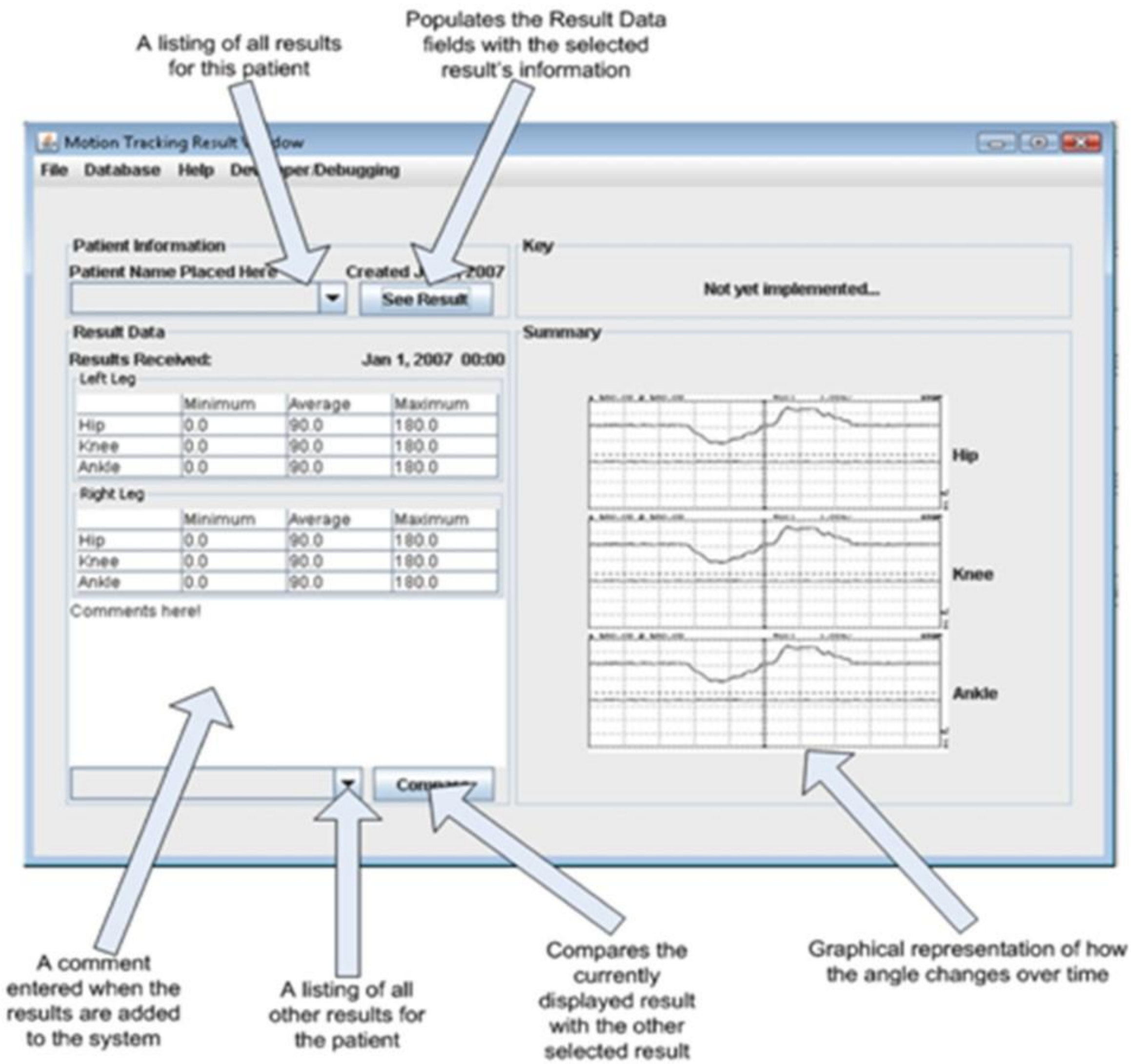

Fig. 7.19. User interface for motion tracking system.

anticipated. Overall, the project was a significant step toward creating an affordable motion tracking system for use in a physical therapy clinic.

The total cost of the project was $1,443.37.

More information is available at https://edge.rit.edu/content/P08006/public/Home

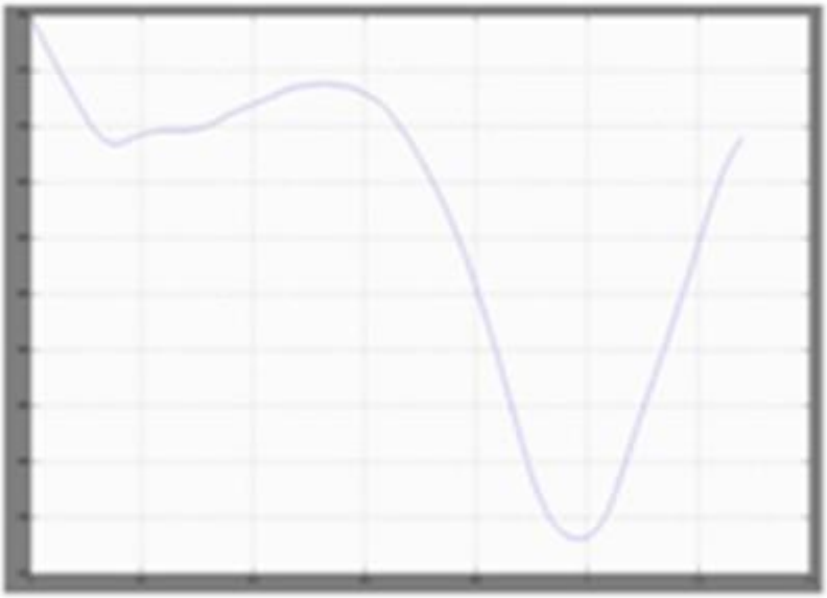

Fig. 7.20. Knee flexion, with a range of 130º-180º.

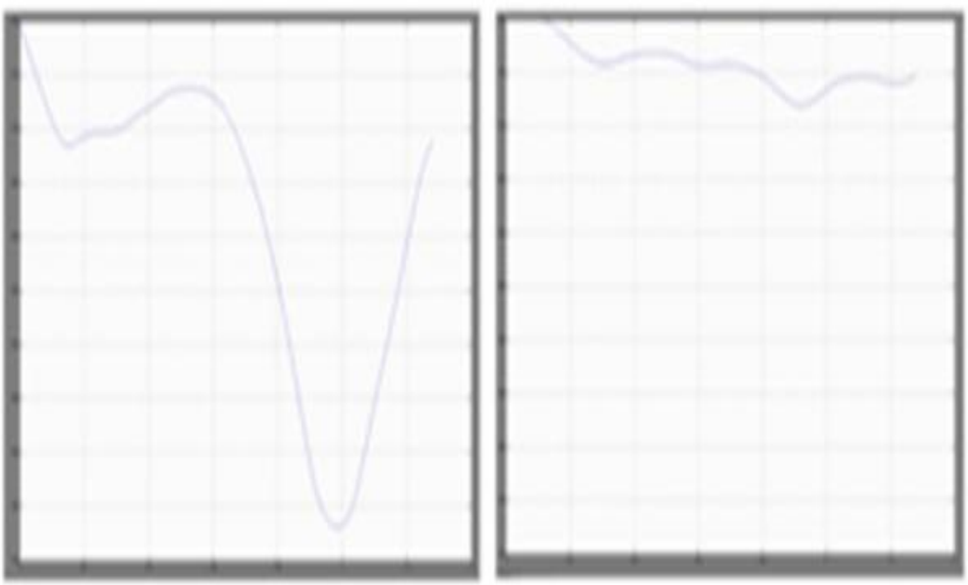

Fig. 7.21. Knee flexion in a normal gait pattern (left) compared with a simulated patient (right).

ARCWORKS MANUFACTURING PROCESS IMPROVEMENT

Industrial Engineering Designers: Eric Meinecke (team leader) and Stephen Morey
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INTRODUCTION

The purpose of this project is to design and build a machine that improves upon a manual process of assembling closure/straw adapter subassemblies that are used Nalgene wash bottles. Problems with the manual process that are addressed with the new design include a long assembly cycle time, a high force input requirement that caused long-term repetitive stresses for the operators, and a tedious loading procedure that is frequently completed incorrectly, resulting in a high part rejection rate. A secondary project objective is to redesign the floor layout of the entire wash bottle assembly cell at ArcWorks to streamline the flow of materials through the assembly process. Figure 7.22 shows the subassembly being created with this machine.

Fig. 7.22. Wash bottle subassembly.

SUMMARY OF IMPACT

A pneumatic device, capable of creating five closure/straw adapter subassemblies simultaneously and keeping an automatic tally of the number of subassemblies made, was successfully built (Figure 7.23). The machine is now being used by employees with a range of mental and physical disabilities at the ArcWorks manufacturing facility. ArcWorks has already expressed their satisfaction about the outcome of this project, making particular note of the ease of use for the employees. Since its installation at ArcWorks, the new assembly machine has replaced all the manual presses previously used to make closure/adapter subassemblies. While the manual presses will continue to be used for small specialty orders, the new machine has become ArcWorks' workhorse for making subassemblies. Additionally, the distance parts travel from raw material to finished product has been reduced from 90 feet to 45 feet through a redesign of the layout of the manufacturing floor (Figure 7.24). The new design also allows the supervisor to see at a glance the stage of assembly of any part, just from his position on the floor.

TECHNICAL DESCRIPTION

The pneumatic system consists of five double-acting cylinders plumbed in series. There is a slight delay between the first and last cylinder to fire, but the lag is insignificant relative to the total stroke time. When the pneumatic cylinders actuate and extend, a guide sleeve housed within a press fixture fits over the straw adapter, and bottoms out on the straw closure. As the cylinder continues to extend, the force presses the adapter into place. The inner core of the guide sleeve has a cavity composed of a series of concentric steps that mate with corresponding faces on the adapter. The concentric steps not only allow the inner core to interface with the adapter in any orientation, they also distribute the total assembly force on the adapter over the maximum possible area, reducing the likelihood of breaking the adapter during assembly. This system is the key to consistently successful subassemblies.

Upon the completion of the machine construction, testing, consisting of filling an order of 1400 closure/adapter subassemblies for ArcWorks, was completed. The objectives of this test were to test the robustness of the structure of the machine and the pneumatic fixtures, to test the pneumatic safety equipment (the two-hand anti-tie down control and emergency stop), to identify any usability issues with the machine, and to compile statistics on the performance of the machine. The 1,400 subassemblies completed had a rejection rate of 0.7% (10 parts). This is significantly better than the average rejection rate of 5% with the current manual assembly process. The cycle time has been reduced from six to four seconds and the force required to assemble the device has been reduced from 50-70 lb. to two ounces (the force required to activate the two-hand anti-tie down control).

The total cost of the project was $1,682.01.

More information is available at https://edge.rit.edu/content/P08008/public/Home

Fig. 7.23. Closure/straw adapter subassembly device in use.

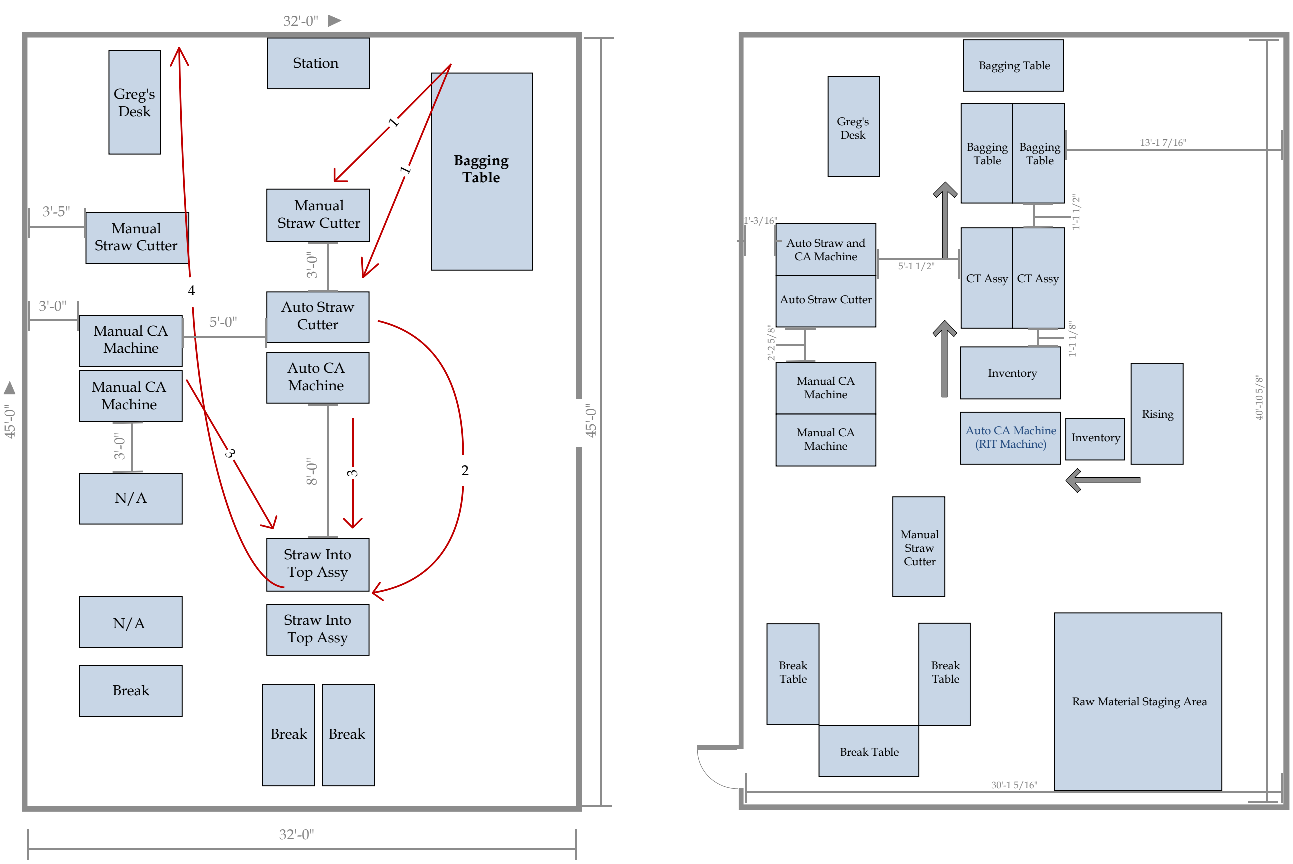

Fig. 7.24. Material flow diagram before (left) and after (right) floor layout redesign.