CHAPTER 9
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ONE–WAY COMMUNICATION BOARD

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INTRODUCTION

A one-way communication board was designed and specially customized to fit the lifestyle and preferences of a client. The client is part of a program that focuses on individuals with mental retardation and developmental disabilities, promoting life-long learning opportunities. This individual can hear and understand others, has normal vision, and uses a wheelchair without assistance, but she has limited verbal and spelling capabilities. The individual currently uses a loose-leaf picture book to communicate with others, but could benefit from a device with speech output to supplement pointing to pictures. The device helps improve the client's communication skills.

SUMMARY OF IMPACT

The team was able to provide the client with a new communication device customized to her needs and tastes. The user interface (see Fig. 9.1) allows for easy browsing through a series of topics. The device is preprogrammed with the names of friends and will say "hello" in additional languages to those friends as desired. In accordance with the customer requests, the team packaged the device in a pink housing (see Fig. 9.2).

TECHNICAL DESCRIPTION

The device is made up of four main components: 1) a Liquid Crystal Display (LCD); 2) a Touch-Screen (TS); 3) a Single Board Computer (SBC); and 4) a battery. The SBC is a miniature motherboard which runs the communication software and maintains the audio and picture databases stored in Compact Flash (CF) memory. The SBC display is hooked up to the LCD/TS, which takes the place of a keyboard and mouse in a normal computer. The client uses

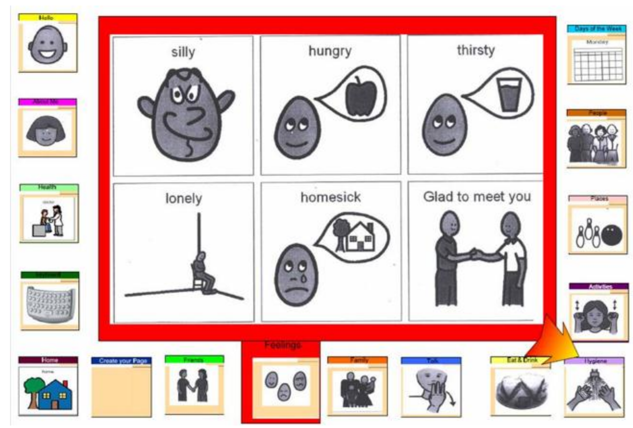

Fig. 9.1. Communication Board GUI Screenshot

the touch screen to interact with the communication software created for the ARC communication board. To provide power to the system, a high-capacity rechargeable battery is used.

The two main constraints that guided the selection of specific components were cost and size. The LCD/touch-screen (#ETL121C-7SWA-1) was donated by Elo TouchSystems. As the touch-screen was the largest physical component in the system, it was possible to focus on the selection of the other components based on engineering requirements: capabilities, size, and cost. The single board computer was chosen based on the minimum specifications to run Linux [3], which included: 1) the speed of the processor (300MHz); 2) the size of the RAM available (128MB); and 3) its ability to use CF as storage memory (two GB). It also required a video output for the LCD and a serial output for the TS, and had to be low-cost. The single board computer selected was an Acrosser AR-M9919.

When the SBC was received, Debian Linux 3.1 (Kernel version 2.4.27) was installed as the OS because it was open-source and one of the popular distributions of Linux, which provided many sources for help. A major problem was encountered when the SBC was configured to communicate with the LCD. The driver installation instructions confirm that the drivers would interface with the Debian kernel, but when they were loaded, they failed due to a kernel mismatch. Debian Linux 4.0 (Kernel version of 2.6.18-4) was then installed as the OS, which required a switch of file type extensions for the drivers. They were successfully recompiled to match the kernel version being used. Upon reinstallation, the drivers were successfully installed and verified.

Other software that was installed was: 1) the X-windows system (aGraphical User Interface (GUI)); 2) Mozilla Ice-weasel web browser (based on Mozilla Firefox); 3) Mozilla m-player plug-in (for playing music files). This software was installed based on the amount of space it occupies on the hard drive and its ability to support the client's needs.

After the software was implemented, a noticeable lag was encountered during screen refreshes. The SBC's RAM was increased from 128MB to 512MB in order to provide increased processing power to the CPU, thus improving the overall performance of the computer and aiding in enhancing the client's experience with the device.

Specifications of similar communication devices (found in "Product Benchmarking") were used to determine a target battery capacity. A lithium-ion rechargeable battery was chosen because the battery was required to supply power to the system for long periods of time at a steady voltage. In addition, the Li-ion class of batteries can provide a high degree of amp-hours required by a high power-drain device. The battery selected was the Powerizer LCH3P6S2R2WR-2P2 which provided 7.4 volts at 15.6 Amp-hours.

Fig. 9.2. Final Communication Board Design.

The software's GUI was developed based on the design requirements specified by the customer and ergonomic analysis. It includes: 1) an active display area (ACDA); 2) menus for each category; 3) scrolling arrows. The ACDA consists of six pictures that deliver a sound and text output when clicked. The scrolling arrows change the ACDA pictures to the next set of six pictures within a category. The category menus load the ACDA with pictures associated with that category.

The product is hosted by a local Apache web server where the user interface is displayed via the Mozilla Firefox web browser. The scripting language, PHP, defines image placement, size, and overall setup. PHP is also used to create background colors, border colors, and text display. JavaScript is used to control client-side interactions (i.e. sound output when an image is clicked). The MySQL database stores the images and sounds to be displayed at the output. All images are in jpeg format and sounds are in wav and mp3 format.

The total cost of the project was about $1705.

TWO-WAY COMMUNICATION BOARD

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INTRODUCTION

When college students who are deaf or hard of hearing seek extra help during professor office hours or tutoring sessions, interpreters are rarely available. Faculty and tutors at a university found that communicating effectively with students who are deaf and hard-of-hearing is challenging. The current method of communication with these students is slow and frustrating, limited to a communication method consisting of handwritten notes. The goal of this project was to design a device that would make communication faster and easier, encouraging more students who are deaf and hard of hearing to visit their instructors' offices for help. The design team interviewed faculty and students to determine what features they would most like to see included in the device and they used these interviews to determine lists of the most commonly used phrases and terms that would be used during office hours or a tutoring session.

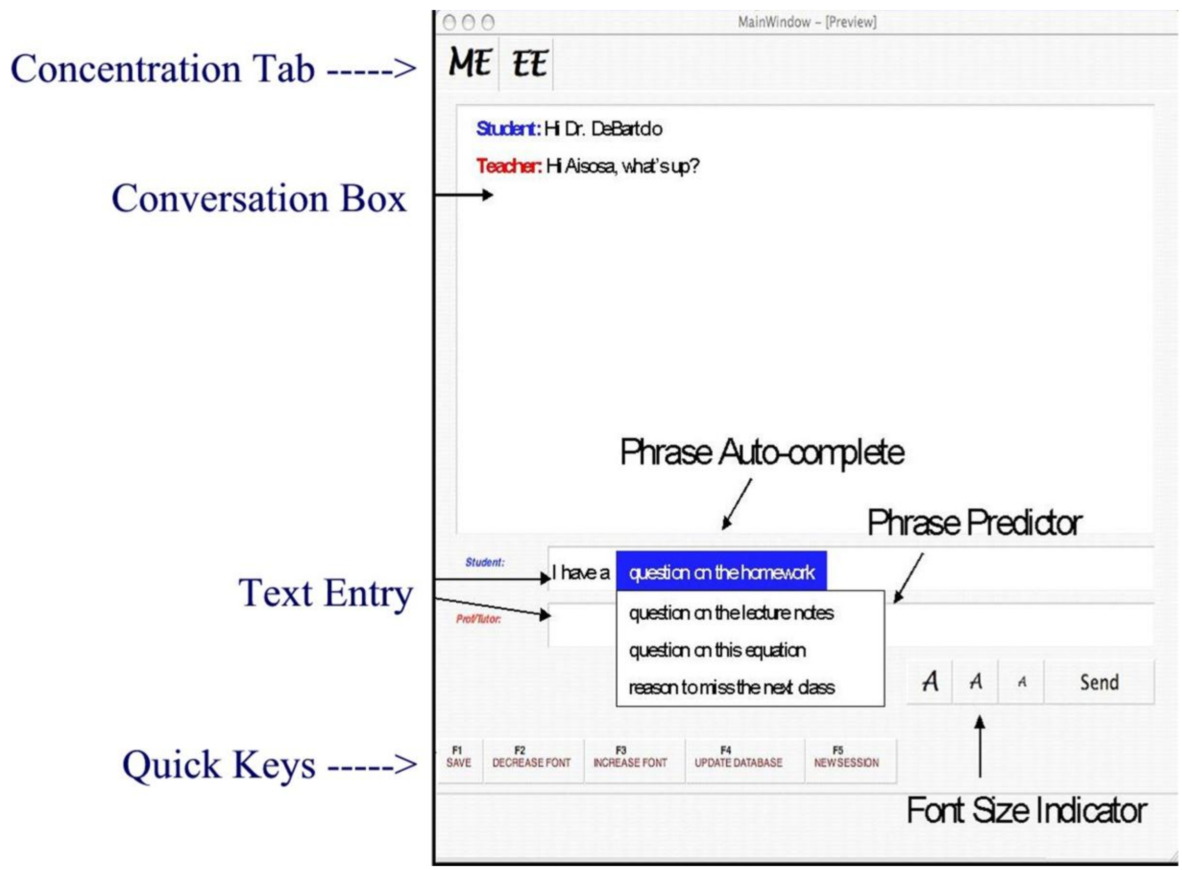

Fig. 9.3. Screen Shot of GUI for Two-Way Communication Board.

SUMMARY OF IMPACT

The project team designed a device that uses a messenger style interface (see Fig. 9.3). The communication method allows users to type to each other with any relevant phrases auto-completed to increase efficiency of communication. This project will enhance the learning experience for students by easing the method of communication with the professor or tutor. The device is powered by a single board computer, with a monitor built into the case and a detachable flexible keyboard.

TECHNICAL DESCRIPTION

The primary hardware components required for the Two-Way Communication device were: 1) a single board computer (SBC); 2) a power supply; and 3) a Liquid Crystal Display (LCD). The single board computer is the brain of the device and is comprised of a micro-processor and memory. Requirements for the SBC include 386 MHz processor speed, 4 MB of RAM, and 40 MB of storage that are driven by the team's decision to run an Embedded Linux operating system. Additionally, the SBC had to fit within the specified casing dimensions. A PCM-9371 single board computer was selected, with 650 MHz of processing speed, 128 MB of DRAM, and a one GB Compact Flash Drive. The 10.4" LCD and SBC were purchased from the same manufacturer, to ensure that the LCD was compatible with its SBC. The power requirement for the PCM-9371 single board computer is 14-Watts and 5-Amps. Initially, the goal of the team was to purchase the hardware components from the same manufacturer to avoid compatibility issues. Hence, the team selected a 150-Watt ATX power supply from the PCM-9371 manufacturer. This was the minimum power supply rating offered that met the single board computer's power requirement. However, this power supply significantly increased the overall case dimensions and violated the design specifications. An alternate power supply that generated 60-Watts was selected from a different manufacturer.

Software development was one of the main components of the project and it encompassed the selection of the appropriate operating system, programming language, and the Graphical User Interface (GUI). Preliminary design for software development started with selecting the appropriate operating system to accommodate the SBC. The embedded version of Debian Linux was chosen as the operating system because of its capability to run with a smaller processing speed than a Windows operating system. Furthermore, the supplier of the single board computer provided a customized version of Embedded Linux along with X-Windows and one year technical support. Programming for the GUI was done in Java, a high-level language that is widely used for GUI development and Web applications. It runs on different platforms such as Windows, Linux, Solaris, and Mac. This cross-platform capability made Java very well suited for the application of this project.

The design of the GUI was developed after several meetings to solicit ideas from students who are deaf or hard of hearing, as well as tutors and professors. An "instant messenger" GUI style design was found to be most effective in meeting client requirements. The GUI was designed to have adjustable font size and the ability to save the session to a flash drive. It also starts a new session with the press of a single key. An auto-complete feature for phrases and sentences was added, which reduces typing time by auto-completing phrases or sentences that have already been typed by another user and added to the database. The suggested phrase and sentences feature also reduces typing time by allowing the user to select from a list of sentences that start with the same word he or she has typed. The device has a database update feature that allows the user to add phrases or sentence to the database.

Currently the design is limited to a single physical device. This means only one student can use the device at any given time. In order to broaden the number of users who can benefit from the design, it is recommended that the software be transformed into a website that any student can access via the Internet. This will allow students to bring their laptops to the professor's office and launch the program immediately. Students would also be able to use the program for more than one purpose including peer-to-peer communication.

The total cost of the project was approximately $1147.

MOBILE CAMERA CONTROL SYSTEM FOR A CANON EOS 1DS MARK II DIGITAL CAMERA

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Client: Dr. Alfred Loeb
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INTRODUCTION

The client, a 79 -year-old retired engineer, was involved in a serious bicycle accident. As a result, his left arm is fully paralyzed and he is severely limited in terms of movement of his head, neck, and right arm. With limited range of motion in his right arm, he was able to lift his hand to approximately shoulder level and could operate a mouse with one finger, but he was no longer able to use his camera because of the dexterity and strength needed to lift it and manipulate its settings. The objective of the project was to design a control unit to allow the client to use his Canon EOS 1DS Mark II digital camera via a user-friendly software interface.

To complete the design, the team constructed a small portable computer with an attached screen to run the user interface. A trackball mouse allows the user to control it. The system made use of the Software Development Kit provided by Canon to access and control settings in the camera's software through a computer interface that the team designed (see Fig. 9.4). The final prototype was thoroughly tested for functionality and durability.

SUMMARY OF IMPACT

Because photography was one of the client's lifelong hobbies, regaining the ability to use his camera significantly improves his quality of life. The device also increases the client's independence.

TECHNICAL DESCRIPTION

The design implementation was divided into three sub-sections: 1) hardware; 2) packaging; 3) software.

Implementation of the hardware began with the selection of the appropriate electronic components. The primary electronic components included were: 1) the Central Processing Unit (CPU); 2) the liquid crystal display (LCD); 3) the hard drive; and 4) the rechargeable battery. The main factors considered in selecting the electronics were: 1) the client's requirements; 2) the project budget; and 3) the compatibility of components. A NEC NL6448DC26-01 LCD screen was donated by a corporate sponsor.

The most essential component was the (CPU). A VIA 10000M Mini-ITX motherboard was chosen. Based on the client requirements, there were several minimum system requirements for the motherboard: 1) one-GHz Processor speed; 2) one and a half GB hard drive space; 3) 256 MB RAM; 4) LCD interface capability; 5) two USB ports; and 6) the ability to add an external hard drive. A Seagate Momentus 5400.2 60 GB hard drive was chosen to provide significant space for storage of pictures. A rechargeable battery was then chosen. Preliminary research had shown that the system would consume approximately 35-Watts of power operating at its nominal state. Thus, it was calculated that a battery capacity of at least 4500-mAhrs would be required, thus NiMH batteries were chosen. The final selection was a 10-cell NiMH 12-volt, 4500-mAhr battery pack produced by BatterySpace with a compatible charger.

The project software was created and implemented using the Canon Software Development Kit (SDK) for camera control and Visual Studio 2005 for the GUI. Windows XP was selected due to its compatibility with the SDK and its availability at a reduced cost.

The software development process followed in this project was different than a normal software development process due to the use of the SDK. The first step in the process for this project was a review of the Canon SDK. Canon had used a modular approach to the SDK, with each function that the camera performs indicated by a software function. The actual code for each function was not available to the programmer, so the way in which these functions performed could not be manipulated. However, the modularity of each function did allow for combinations of functions to perform more complex steps. For instance, a function like downloading a picture or taking a picture could not be modified, but the two codes could be combined in order to tell the camera to take a picture and download it in response to one command from the user. Each function was implemented linearly; one function was completed and tested prior to implementation of the next function. This allowed for performance review of the software at each step in the process. Regression testing was completed at each step of development, so if problems emerged, the fault could always be traced to the last code added.

The final packaging design consisted of a rectangular box with a hinged lid for adjusting the screen angle and a three-sided bellows to enclose the internal components while still allowing movement of the lid. The case was constructed from an aluminum frame with plastic sides to reduce the overall system weight. Static-dissipative ultra high molecular weight polyethylene (UHMWPE) was chosen as the plastic used for the outside of the case because of its: 1) high durability; 2) strength; 3) resistance to static charge; and 4) recycling purposes. The amount of heat dissipated by the enclosed electronics was calculated to determine whether any additional heat removal systems would be required to prevent overheating of the system. The heat energy generation, at maximum power use, was estimated to be 39-Watts, and the maximum allowable temperature for proper operation of the electronic equipment is 50^{o} C. It was found that with a room temperature of 25^{o} C and the given surface area of the box, the surface temperature would have to be at least 70^{o} C in order for 39-Watts of thermal energy to dissipate through natural convection. Thus, ventilation holes and air circulation were required. To determine the required mass flow rate of air through the system, all sides were assumed to be perfectly insulated, with all heat transfer occurring by removal of warm air. The resulting required volume flow rate to keep the inside of the case below 50^{o} C was calculated to be 4.5 ft^3/min, so a fan with a flow rate of 7.4 ft^3/min was installed. Once the system was assembled, heat levels inside the case were measured while the system was running to ensure that temperatures were within acceptable levels.

The total cost of the project was approximately $1168.

Fig. 9.4. Screen Shot of Camera Control GUI.

ADAPTABLE POOL LIFT SEAT

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Mechanical Engineering Designers: David Alas, Alecia Eppelsheimer, Jeffrey Klaus, and Brian Walsh
Client Coordinator: Heather Margeson, Arc of Monroe County
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INTRODUCTION

A 2005-06 senior design team had built a lift mechanism that could lower people into a pool as well as raise them out. A new seat for the lift was requested to better fit variable client needs, such as the degree of incline of the seat required. Additionally, staff users of this new lift requested the ability to get one individual in the locker room ready for a pool session while another is being wheeled out and lowered into the pool.

The final project is a PVC frame with a custom hinge design that allows the seat to operate in either an upright or a reclined position. Six removable stainless steel casters allow a therapist to transport the user from the locker room to the pool deck and a forklift-like linkage allows the integration of the new chair into the existing lift system. Fig. 9.5 shows the final chair design. Two chairs were constructed to allow personnel to prepare two individuals for pool sessions at once.

SUMMARY OF IMPACT

The chairs better fit the needs of the clients and aid the staff in helping the clients.

TECHNICAL DESCRIPTION

Once a final design concept was chosen, calculations were performed to determine the minimum PVC pipe size that would support the weight of the users. The entire system was then modeled and simulated using ANSYS. The system was determined to be feasible, passing with a maximum Von Mises Stress that was well below the yield stress of the PVC with a factor of safety of two.

Upon finalization of the design, the first prototype was constructed using PVC pipe and fittings. This was not glued during the initial phase of construction so that pipe lengths could be adjusted to allow proper alignment of all sections of the seat assembly. Once the entire seat was assembled properly, it was disassembled and all sections of pipe were measured for final length and labeled. The seat was then reassembled using PVC cleaner and cement. The seat was assembled from the inside out, with the front hinge glued first, followed by the rear hinge and seat back subassemblies that had sections passing through the front hinge. The armrests, footrest, and diagonal braces were built next. The main seat frame was built last, with sections passing through all of the other subassemblies. The adjustable end of the footrest and the caster assemblies were constructed separately and attached with removable stainless steel pins. This process was repeated for the second prototype. The seat material (Phifertex Plus®, a PVC-coated polyester mesh) was sewn to fit the completed assemblies, and the three sections (seat bottom, seat back, and foot rest) were then attached to the seat assemblies using Sta-Set® polyester rope.

Fig. 9.5. CAD Model of Final Product.

The linkage was constructed of stainless steel tubing. Four square tubing sections were welded together to form a rectangle. Two round tubing sections were then welded perpendicular to the rectangle to form the "forklift" arms. On the back of the rectangle, two rectangular sections were welded vertically in the middle to form an attachment point for the lift.

Extensive testing was performed on the seat components (see Fig. 9.6). First, a 16" x 22" x 13" L-shaped PVC frame was constructed using 2" diameter PVC pipes, two three-way fittings, and four elbows. The frame was dropped from varying heights to simulate a sharp impact or blow to the chair frame. The frame was originally dropped from a height of three feet and progressively increased in order to have the frame fail. Again, a failure was considered a significant crack in the pipes or a separation of the joints. Next, a 50-lb weight was dropped on the same L-shaped frame from varying heights while the frame rested and supported on the ground. Finally, a standard three-point bend test was performed on corroded and pristine cemented PVC sections to determine the effect of bromine in the pool on the adhesive. In both cases, failure occurred in the coupling rather than at the adhesive.

The total cost of the project was about $1463.

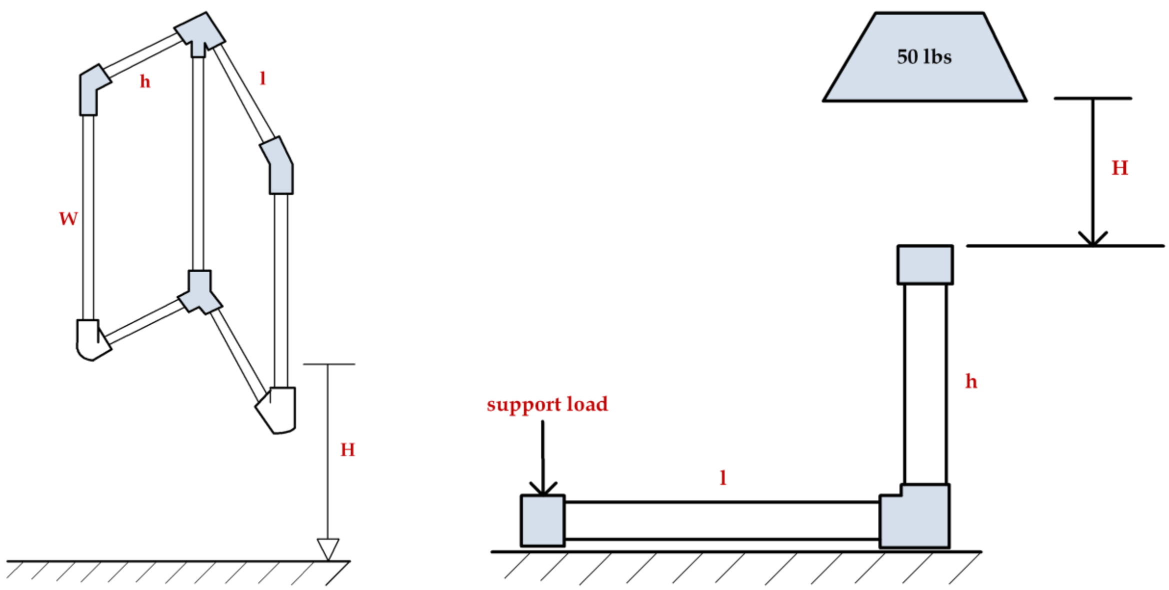

Fig. 9.6. Schematics of Drop Test and Weight Test.

UPPER EXTREMITY EXERCISER

Industrial and Systems Engineering Designers: Eduardo Borges, James Letts (team leader), Christopher Reed, and Renzo Salazar
Mechanical Engineering Designers: Dennis Bradford, Daniel Kelly, Park Perkins, and Julie Watkins
Client Coordinator: JJ. Mowder-Tinney, Nazareth College Physical Therapy Clinic
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INTRODUCTION

The objective of this project was to create a rehabilitation aid for individuals recovering from stroke or other neurological traumas. It was to facilitate stretching and strengthening exercises to help lift and reach for objects. A physical therapist requested that the device provide assistance throughout a lifting motion and constrain arm motion to the sagittal plane. The device was to: 1) provide an adjustable, assistive force to help lift the arm in front of the client; 2) be adjustable for height and weight; 3) be able to be used on the left or right arm; and 4) be portable while in the use phase.

The final product (see Fig. 9.7) consists of an acetal beam that extends over the client's shoulder. The beam is tapered to a thinner width and thickness toward the end in order to create more flexibility while maintaining strength at the base. Attached to the beam is a rubber exercise band that, in turn, attaches to the hand or wrist of the client at the therapist's discretion. The combination of the flexible beam and rubber cord creates a force that assists in lifting the arm of the client up and away from the body in the sagittal plane. The amount of assistive lifting force can be varied between 4.4 to 8.3 pounds by turning a ratcheting hand crank, thereby increasing the initial tension on the exercise band.

SUMMARY OF IMPACT

The device aids the physical therapist and clients during upper-body rehabilitation.

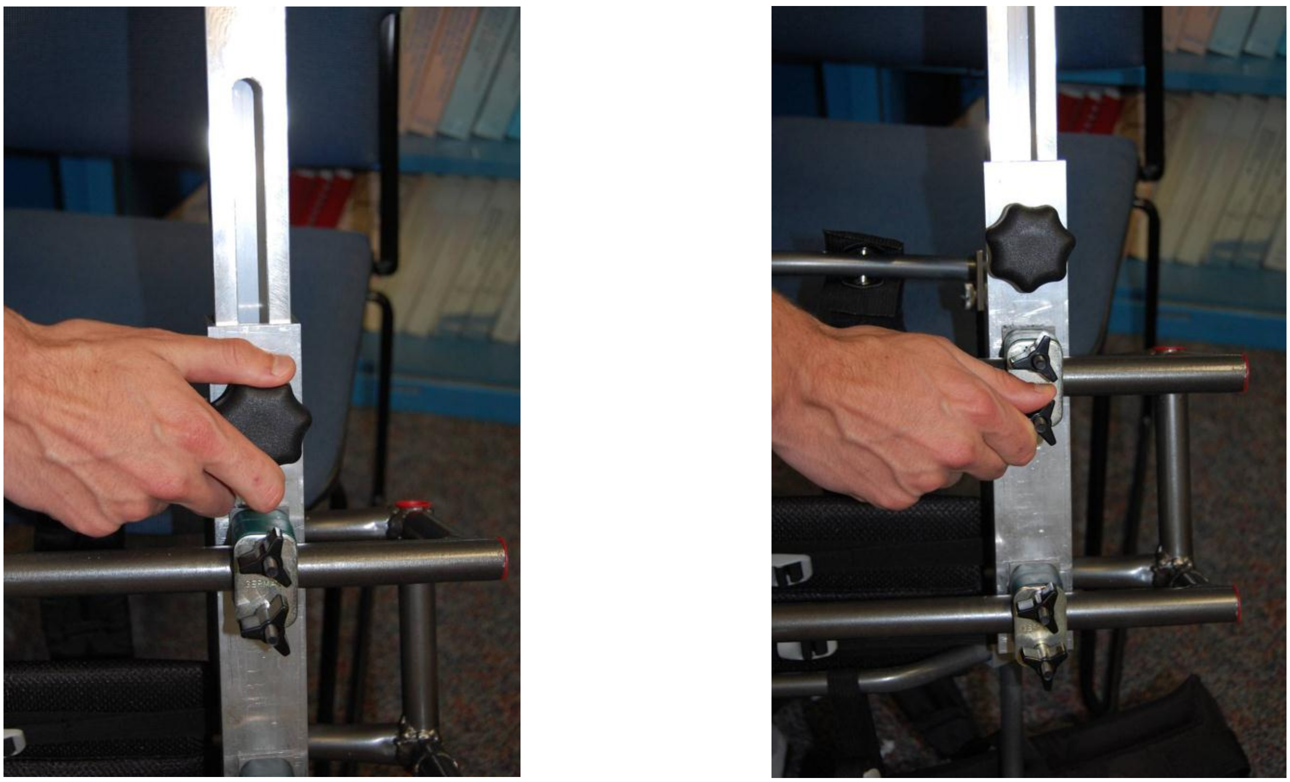
TECHNICAL DESCRIPTION

The final product is a cantilever beam assembly mounted on a lightweight backpack frame (see Fig. 9.7). The device slides horizontally on two rails attached to the frame and vertically in a sleeve mounted to the frame (see Fig. 9.8). All adjustments can be made by hand. The hand attachment point is interchangeable with a number of different hand grips, depending on the ability of the user. The cable running to the hand grip passes through a telescoping guide that maintains motion in the sagittal plane. The mechanical assistance is provided by an exercise band that runs from the hand grip, down the length of the beam, and back to the vertical post.

Fig. 9.7. Student Team Member Demonstrating Use of Upper Extremity Exerciser.

The cantilever beam was made from acetal, and extends over the client's shoulder. The project started with a wider beam machined to a smaller size to determine the actual stiffness of the material supplied. Attached to the beam is a rubber exercise band that attaches to the client's hand or wrist at the therapist's discretion. As with the acetal, the exact modulus of the exercise band was unknown and had to be determined experimentally. The combination of the flexible beam and rubber cord creates a force that assists in lifting the patient's arm up and away from the body in the sagittal plane. The completed device was used with a BTE II Simulator machine to determine the actual lifting forces. The physical therapy clinic was also provided with a calibration scale to enable therapists to set the amount of lifting force by tightening the exercise band with a certain number of turns of the ratcheting mechanism.

The total cost of the project was about $649.



(a) (b)

Fig. 9.8. (a and b): Vertical Adjustment (a) and Horizontal Adjustment (b) of Device Mounted to Backpack Frame.

PHYSICAL THERAPY CLINIC LAYOUT REDESIGN

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INTRODUCTION

The goal of this project was to improve the layout of a physical therapy facility in order to improve effective utilization of the facility and its equipment. Therapists at the clinic cited several examples of problems with the facility and instances in which the existing conditions had prevented them from delivering the best care possible to their clients. Using multiple pieces of equipment at the same time was problematic (see Fig. 9.9). The therapists had to work around one another and sometimes would not use particular pieces of equipment because of the lack of free space.

SUMMARY OF IMPACT

By reorganizing the clinic, the team was able to make significant improvements in both free space and accessibility of existing equipment. The new layout reduced the amount of overlap in work space from almost 300 ft^2 to just over 30 ft^2, and areas where work space overlapped among pieces of equipment were reduced from 120 ft^2 to 3 ft^2. Free space in the clinic was increased by 238 ft^2. In addition, a ramp and a platform (50- and 55-lb, respectively) used for therapy were modified to be more mobile so they can be taken out only when needed. By adding handles and caster wheels, the force needed to move each item was reduced to 17 pounds.

TECHNICAL DESCRIPTION

Halo diagrams were created to estimate the amount of overlap between equipment spaces. The halo is

Fig. 9.9. Physical Therapists Attempting to Use Neighboring Pieces of Equipment in Clinic.

the area around a piece of equipment required to use it. Physical therapy clients require constant supervision when using the equipment, so 30” halos were drawn surrounding each piece of equipment. The clinic was reorganized as shown below. Fig. 9.10 shows the old layout with halos indicated by dashed lines and Fig. 9.11 shows the new layout.

The total cost of the project was $0.

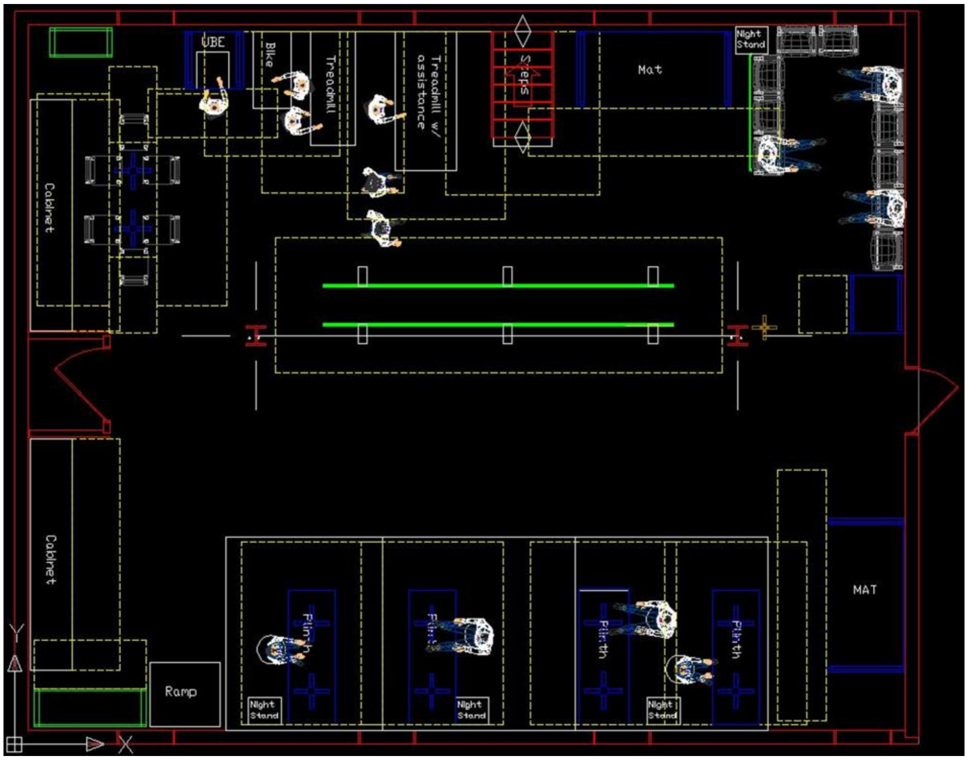

Fig. 9.10. Old Clinic Layout; Dashed Lines Indicate Halo of Space Required to Use Each Object.

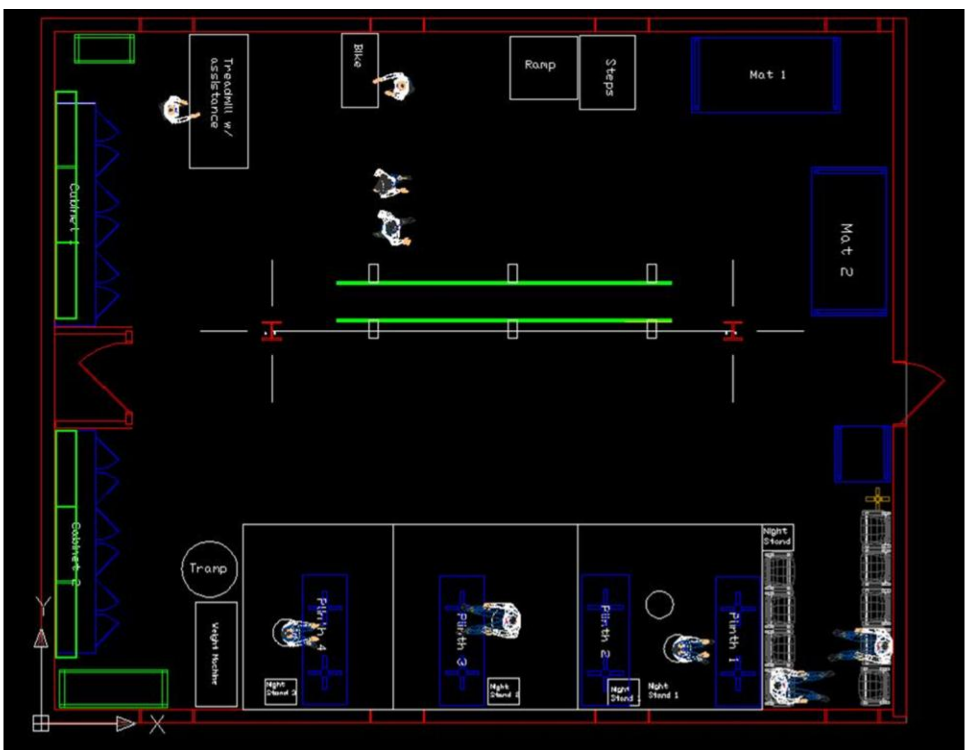

Fig. 9.11. New Clinic Layout After Useful Equipment was Moved to Optimal Positions and Unused Objects Were Cleared.

AUTOMATED HOME ENTRY CONTROL SYSTEM

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INTRODUCTION

A 2005-06 project entailed an adapted home entry system designed to give home access to two individuals who use wheelchairs and were unable to open their home's front door without assistance. The system was designed so that the two individuals would be able to enter and exit their home without any assistance. By utilizing a remote control system, the clients could open, close and lock the home's front door. The opening and closing of the door was implemented using an electric motor driving a mechanical lever attached to the door's upper surface. The locking capability was provided by incorporating an electric strike plate. A prototype system was initially implemented to

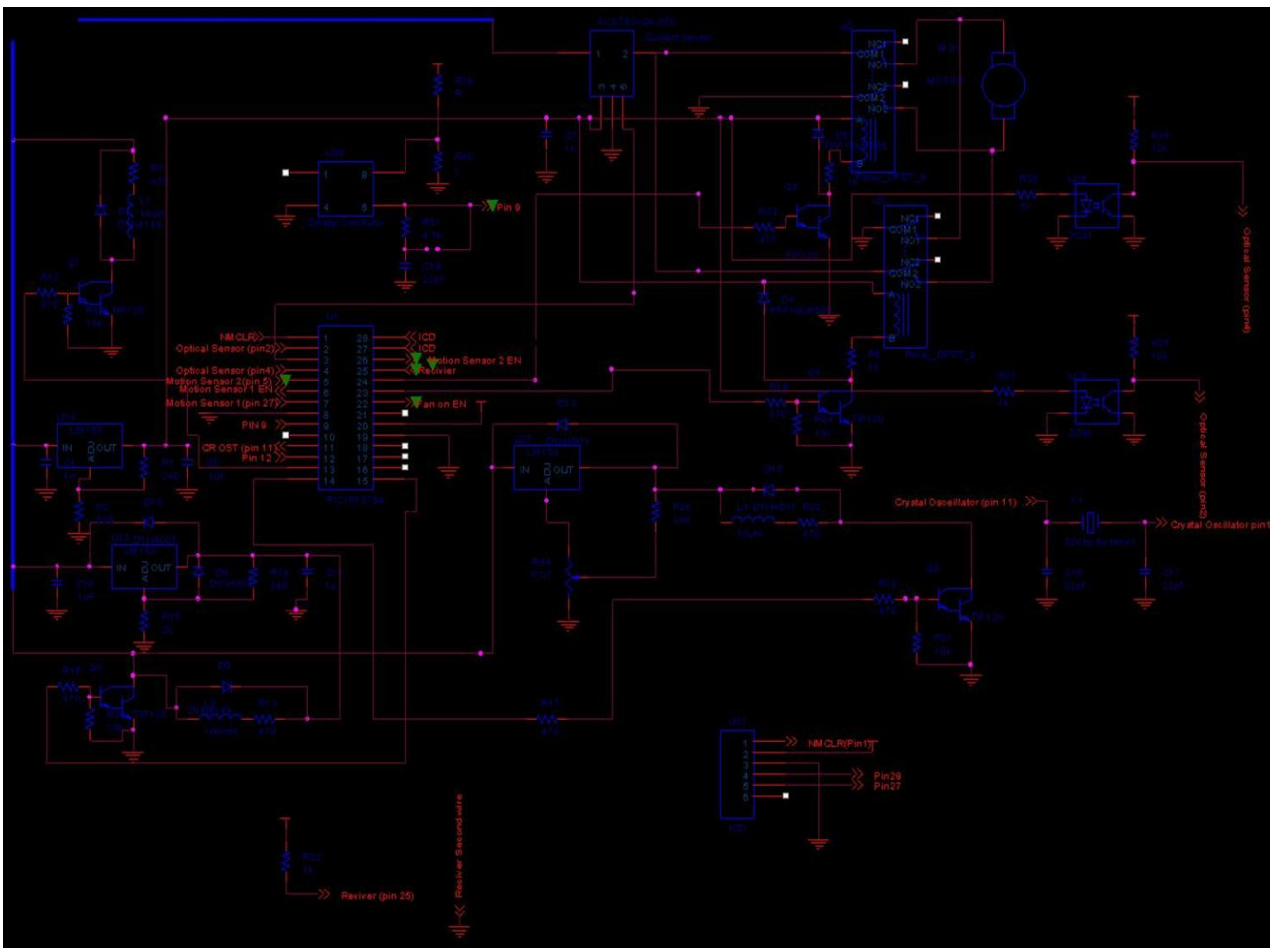

Fig. 9.12. Control System Schematic Diagram.

demonstrate the feasibility of providing an integrated solution. The original prototype system stopped functioning properly after a short period of time. The management agency associated with the operation of the group home requested that: 1) the prototype system be removed; 2) any modifications to the original doorway be repaired; and 3) any revised system be tested and approved prior to its installation. The task was to build a robust control system for the existing electro-mechanical hardware that met the original requirements, including those associated with the Americans with Disabilities Act.

The original system was viewed in its failure mode. The resulting discussions, review, and analysis provided the impetus to design a more integrated and sophisticated electronic control system, as well as a more robust enclosure and mounting strategy. After the inoperative system prototype was uninstalled, the entire door and door frame assembly was removed and replaced with new construction. It was agreed that the new revised design would be implemented and tested on a mock-up comprised of the old door and door frame to the complete satisfaction of the management team of the residence before it was actually installed at the residence.

SUMMARY OF IMPACT

The new design includes a number of improvements, including a new enclosure and the use of printed circuit boards for the electronic control circuitry. The control system was designed to be more robust. It incorporates a programmable microcontroller and multiple non-contact sensors to ensure safe operation of the door in case the door is obstructed. The system also enables manual operation by other residents of the house or if power to the system is interrupted. The prototype system was well received by both the residents and management associated with the residence. They endorsed the redesign and looked forward to its installation.

TECHNICAL DESCRIPTION

The system entails remote radio frequency transmitters that communicate with a radio frequency receiver unit mounted in the door opener enclosure. The signals from the receiver and from a combination radio-frequency or infrared proximity sensors, a motor current sensor, and non-contact position sensors are used to determine the position of the motor shaft that drives the mechanical door opening assembly. These signals serve as control inputs to a PIC 16F876A microcontroller that is programmed to operate the door in a safe and controlled fashion. The major outputs controlled by the microcontroller consist of: 1) the drive input signal to a 90-volt DC motor; and 2) the activation signal to an electromechanical clutch, which transfers force from the motor to the mechanical door opener mechanism, sending a signal to the electromechanical door strike mechanism to lock and release the door. A system-level 120-volt power supply provides appropriate DC voltage levels for the motor, clutch, door strike, and control circuitry. The power for the overall unit is provided by a standard 15-ampere, 125-volt AC outlet.

The team designed a robust enclosure and mounting platform for the device, with a great deal of advice and assistance from one of the mechanical engineering machine shop technical staff,. The new enclosure was fabricated from aluminum sheet. It includes a cooling fan for the electronic circuitry and the electromechanical devices that comprise the system.

The total cost of the project was about $1185.

ARCWORKS WASH BOTTLE ASSEMBLY ADAPTATION

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INTRODUCTION

The purpose of this project was to develop an assembly system that would improve the existing process of manually attaching a spout to a wash bottle and to reduce the material flow issues of a local facility. The existing bottle assembly required the operator to apply between 40 and 50 lbs of force to attach the spout to the bottle. This was done with a T-shaped manual tool that caused significant contact stress on the user's hands, which was then transferred to the wrist and arm (see Fig. 9.13). Residual effects of this repetitive action ranged from reduced productivity, to pain and discomfort that could result in disability.

The system consists of a pneumatically operated machine that minimizes the force and motion required to assemble the wash bottle (see Fig. 9.14). The operator inserts a bottle into the bottle holder and a spout into the plunger, moves the slide latch into position, and activates the two hand tie-down. The new process reduces the force exerted by the operator from 40 to 50 pounds to less than one pound. In addition, lean manufacturing concepts were incorporated in order to provide a more efficient and smoother material flow. The material flow is one-piece and was standardized so that it is clear to the user where the raw materials and the final assemblies are to be placed.

The device was tested extensively, including a simulated six months of use (54,000 cycles), ten consecutive E-stop firings, and assembly of two full cases of each bottle size to ensure zero defects and improved cycle time over the current process.

SUMMARY OF IMPACT

The overall system ensures greater productivity by having relieved virtually all ergonomic hazards and through reduced material handling distance. Force and motion required to assemble the wash bottle are reduced with the design.

Fig. 9.13. Current Assembly Process.

TECHNICAL DESCRIPTION

Since the bottle assembly was automated with this design solution, engineering analysis was done to establish how the bottle would behave under the pneumatic loads, in addition to determining how the assembly machine itself would react to the force being applied by the pneumatic cylinder. All static analyses were made either using ANSYS version 9.0 or ANSYS Workbench version 10. Three different sized bottles are currently being assembled by employees: 250-mL, 500-mL, and one-L. The one liter bottle was used for all analyses since it undergoes the most deformation of all three due to its size. The bottles are manufactured by Nalgene and are made using low density polyethylene. Analysis showed that the maximum force that can be applied before the yield strength of the bottle is reached is 175-lb. Since the air cylinder used in the design will be running at an air line pressure of 80-

psi (which gives a cylinder force of 72-lb), the bottles would have a factor of safety of 2.43. The most critical part of the assembly system is the bracket that supports all force applied by the pneumatic cylinder; its factor of safety was found to be 10.2.

The first, and one of the most important features of the system, is the OSHA compliant "lock-out-tag-out". This allows the system to be safely depressurized when not in use, and must be un-locked by a supervisor to begin production. Immediately following the "lock-out-tag-out" is a filter/regulator unit with an indicator to regulate the incoming air pressure to the specified 70 to 80-psi. Post regulator is an E-stop which will vent all potential energy in the system.

The heart of the system is based on the two-hand-tie-down feature. The two pneumatic push buttons are placed in line with a pneumatic logic controller. The buttons must be depressed within a half second of each other to generate an output from the logic, ensuring that the operator's hands can only be on the buttons when the machine fires and not in danger from the moving cylinder. Air is then sent directly from the supply through a limit valve to the cylinder, upon which there is a flow control for the forward stroke. When the cylinder extends to the point of a "good assembly", a ball actuator valve is initiated, indexing the counter and pressurizing the green indicator to signal the operator of a completed assembly. The buttons are then released and the cylinder returns to its rest position. The pneumatic schematics are shown in Fig. 9.15.

The total cost of the project was about $1105.

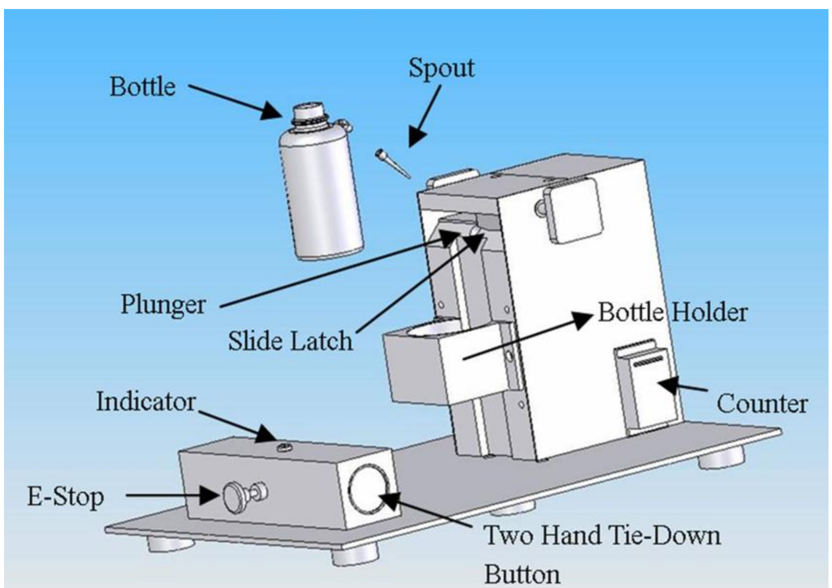

Fig. 9.14. New Wash Bottle Assembly System.

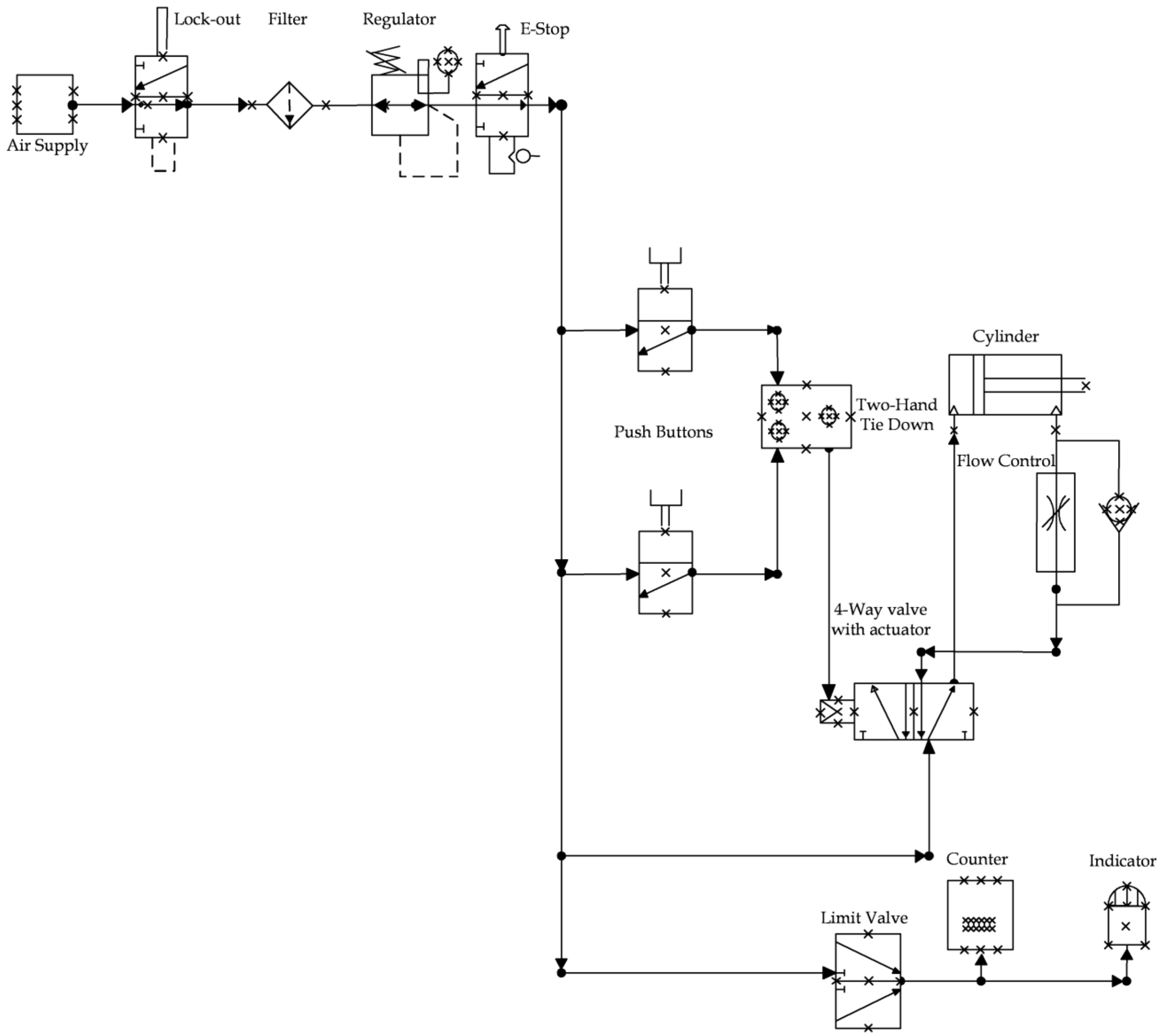

Fig. 9.15. Pneumatic Schematic for Automatic Wash Bottle Assembly System.