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INCORPORATING ASSISTIVE TECHNOLOGY INTO SENIOR DESIGN PROJECTS

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Abstract

Assistive technology (AT) is technology that is adapted to assist people, in the form of a device or service, with disabilities. ABET accreditation standards require students in accredited programs to complete a capstone design project, or class, as part of the curriculum. In order to meet this requirement, two groups of engineering students designed and built two different AT devices for two disabled children in northwest Tennessee for their capstone design project during the 2007-2008 academic year. This project was funded by an external grant. The first child has been identified with cerebral palsy resulting in limited body control and requiring adaptive seating. The parents had difficulty finding games and toys that were appropriate and educational for the child's condition. In particular, the parents suggested to the design team a new learning system that demonstrated the concept of cause and effect to the child. The second child was born with a congenital genetic disorder known as 1p36 deletion syndrome. This child has weak muscle tone and is unable to stand without help, but has head control, limited trunk control, and the use of arms and hands. To develop muscles in the legs, the child is positioned vertically in a prone stander. The child's existing prone stander was mobile, but in order to move, the child was completely dependent on someone else. The parents suggested to the design team a new prone stander that was motorized and that could be controlled by the child. Both AT projects allowed the opportunity for the engineering students to directly interact with the children and their parents during the development. In this paper the authors discuss the details of both projects, including motivation, design process, and the final products.

1. Introduction

The University of Tennessee at Martin (UTM) is a four-year university in northwest Tennessee with a total enrollment of more than 7000 students. Like at all ABET accredited engineering programs, students are required to complete a capstone design project. At UTM, the design project is covered in three classes:

(1) ENGR 409	Engineering Design and Project Management
(2) ENGR 410	Senior Design I
(3) ENGR 411	Senior Design II

ENGR 409 Engineering Design and Project Management is a two- hour class and ENGR 410 Senior Design I is a one-hour class, and both are taught in the fall semester. ENGR 411 Senior

Design II is a three-hour class taught in the spring semester. There is only one section of ENGR 409, while there are three sections of ENGR 410 and ENGR 41l. There is a civil section, an electrical section, and a mechanical section. Since there are only a small number of industrial students, these students can enroll in any section. At the end of the semester, the faculty advisor will report the student's final grade to the faculty member assigned to one of the three sections.

Previous projects include competition projects such as the ASEE Mini-Baja Competition and the IEEE Hardware Competition, redesigning existing bridges and corresponding highways for increased traffic flow, and redesigning manufacturing plants for increased efficiency. The main requirements for the projects include substantial design, more than one possible solution, and finishing the project in two semesters. This is the first time that senior design projects at UTM included assistive technology. However, a literature search quickly reveals assistive technology projects at other universities [1, 2, 3].

At the beginning of the fall semester, all students enrolled in Senior Design I meet as a group with engineering faculty members. There are two main reasons for this meeting, both of equal importance. First, the departmental syllabus for Senior Design I and II is handed out and discussed. The expectations of the class are explained to the students. Another reason is to ensure that each student has a senior design project and an advisor. Many if not most of the students already know which project they will be working on and have already began talking with their advisor. For those students who are undecided, this presents an opportunity for the faculty to pitch their project.

One of the authors (RH) co-wrote a grant with UTM Department of Education for an AT grant from the state of Tennessee. The grant proposal was successful and funded the two projects that will be discussed in this paper. The grant proposed to work with several families with a disabled child in West Tennessee with possible AT projects. After receiving the budget from the state, it was decided to work on two of the assistive technology projects. The other two authors (JM and SS), serving as senior design faculty advisors, chose specific projects after consultation with a social worker that worked with the aforementioned families. Since the authors are electrical engineers, the two projects chosen were electrical in nature, and were thought to be challenging enough to take two semesters to complete.

Six students were interested in the assistive technology design projects. They were divided into two teams of three with a rough idea of the project they would be working on. Each team along with their faculty advisors visited the respective families very early in the fall semester. From the very beginning, the advisors felt that it was very important for the students to know the families and have a connection with them since the projects they were working on were going to directly affect the families. During the initial visit, the family explained to the teams what they were expecting. Each team met with their faculty advisors within a week of the initial visit to discuss their findings and impressions. With the first family, the project itself was very open-ended. The team discussed various ways to fulfill the parent's request while at the same time fulfilling senior design requirements. With the second family, the requested project was very cut and dried, but was not sufficient for a senior design project. So, additional requirements were discussed. The teams visited the two families for a second time in a timely manner and proposed the assistive technology projects. Both families were satisfied with the proposed projects.

2. AT Project 1: Head Tracking for Computer Control

The first child has cerebral palsy. This child has limited body control and requires adaptive seating. The parents had difficulty finding games and toys that were appropriate and educational for the child's condition. In particular, the parents wanted a system that demonstrated the concept of cause and effect. The design team decided to accommodate the parent's request by using head tracking software to control and play educational computer games that were developed by the team. In this project, all three students contributed in choosing the hardware components and each student developed different computer games.

Figure 1 Head Tracking for Computer Control Device

As shown in Fig. 1, the project can be divided into the following major sections:

(A) Head tracking device
(B) Computer Stand
(C) LCD Monitor
(D) Computer
(E) Software/Games

The design team researched various systems of controlling computers by tracking head movements. The design team decided on Naturalpoint's SmartNAV system. Reflective tape is placed on the child's head. An infrared (IR) camera and IR source is placed on the top of the computer monitor. The camera monitors the reflected IR light to track head movements. This is a hands-free mouse alternative that allows complete control of a computer by naturally moving the head. Instead of clicking a mouse, the SmartNAV system monitors how long the cursor is "over" a particular icon. This time is adjustable.

A mobile, adjustable computer stand was needed for this project. The design team chose an Ergotron Neo-Flex Mobile Workspace. It is commonly used in hospitals, schools, and businesses. It is designed to be used with a full size desktop or laptop PC.

The design team made a few modifications. The keyboard tray was removed. There was no need for it. The original LCD arm was replaced with a more flexible LCD arm, the AFC12 flat panel monitor arm. The parents requested that the child be able to lie flat on his back and look straight up at the monitor.

The family requested several displays or one large display. The design team decided that only one reasonably sized LCD monitor was needed. The design team chose a Sceptre X22wg-Gamer 22 inch LCD monitor.

The design team did not want a huge computer. They wanted a computer about the size of a Mac Mini, but did not want a Macintosh. They chose a Systemax Impact2 mini PC. It was 6.5" X 6.5'' X 2 ". It came with a Intel Celeron M 440 processor (1.86 Ghz, 533 MHz Front Side Bus, and 1 MB cache). It has 512 MB of DDR2 memory and a 60 GB hard drive. Logitech Cordless Desktop wireless keyboard and mouse were purchased so the parents could update/use the computer.

The design team chose the Microsoft Visual Studio software environment to design their educational games/activities. Initially they chose C++ but quickly changed to Visual Basic. The design team developed several educational games/activities. Six of the games are described below.

Block Game - This was the first game that was written. The screen is divided into blocks (squares) that are colored gray. The child simply moves the cursor across a particular block and it changes color. No clicking is necessary. There are two options to the game. Option 1 has the block returning to gray once the cursor moves to a new block. Option 2 leaves the block in its new color. Initially, there were 25 blocks on the screen. The family suggested that this was too much. The final game has 4 blocks covering the screen. Several other games were developed from this game. This game was developed to help the child learn to move the cursor around the screen by moving his head.

Alphabet Game - There are 26 pictures on the screen. Each picture corresponds to a particular letter. For example, there is a picture of an apple for the letter A and a picture of a zebra for the letter Z. As the cursor moves across a particular picture, the picture disappears and the corresponding letter appears. The letter is also pronounced in the voice of the child's mother. The process is repeated. The game was developed to help the child learn the alphabet.

Instruments Game – Pictures of musical instruments form a border around the computer screen. The child selects a particular instrument by moving the cursor on top of a particular instrument. When an instrument is selected, a short audio sample of that particular instrument is played. The process is repeated. This game was developed to help the child learn musical instruments as well as for entertainment.

Uncover Game - The uncover game was designed to incorporate directions and sounds into one game. A picture is hidden beneath four blocks. As the mouse cursor moves to a block, that block is removed revealing a part of a picture. The cursor is moved across all blocks until the hidden picture is completely revealed. After the full picture becomes visible, a fun, short, sound is played. The game is similar to the block game. The game was developed to help the child learn directions.

Directions Game - A picture was randomly placed on an otherwise blank screen. The object was for the child to look at the picture. The game would instruct the child to look up, look down, look right, and look left. The directions obviously depended on the relative positions of the cursor and the picture. The game played previously recorded directions. The voice of the child's mother was recorded telling the child various directions to look. After the cursor entered the picture, the child was congratulated in the mother's voice, and the picture would move to a new position on the screen. The process was repeated. The game was developed to teach the child basic directions.

Movie Application – The family informed the design team that the child enjoys watching cartoons. The child really enjoyed the Baby Einstein series of DVDs. A program was written to display the eight covers of baby Einstein DVDs on the right side of the monitor. Baby Einstein movies are a highly acclaimed set of educational videos for small children. The child could select a particular video. The video played in a viewing window on the left side of the monitor.

3. AT Project 2: Motorized Prone Stander with a Touchscreen Computer

The second child was born with a congenital genetic disorder known as 1p36 deletion syndrome. This child has weak muscle tone and is unable to stand without help, but has head control, limited trunk control, and the use of arms and hands. To develop muscles in the legs, the child is positioned vertically in a prone stander. The child's current prone stander was mobile, but in order to move, the child was completely dependent on someone else. The parents requested a prone stander that was motorized and that could be controlled by the child. The advisors felt that this alone was not sufficient for a senior design project. The design team decided to accommodate the parent's request and include a touch screen computer with educational games and activities that were developed by the team. In this project, two students spent their time on motorizing a prone stander while one student spent time on developing the educational games.

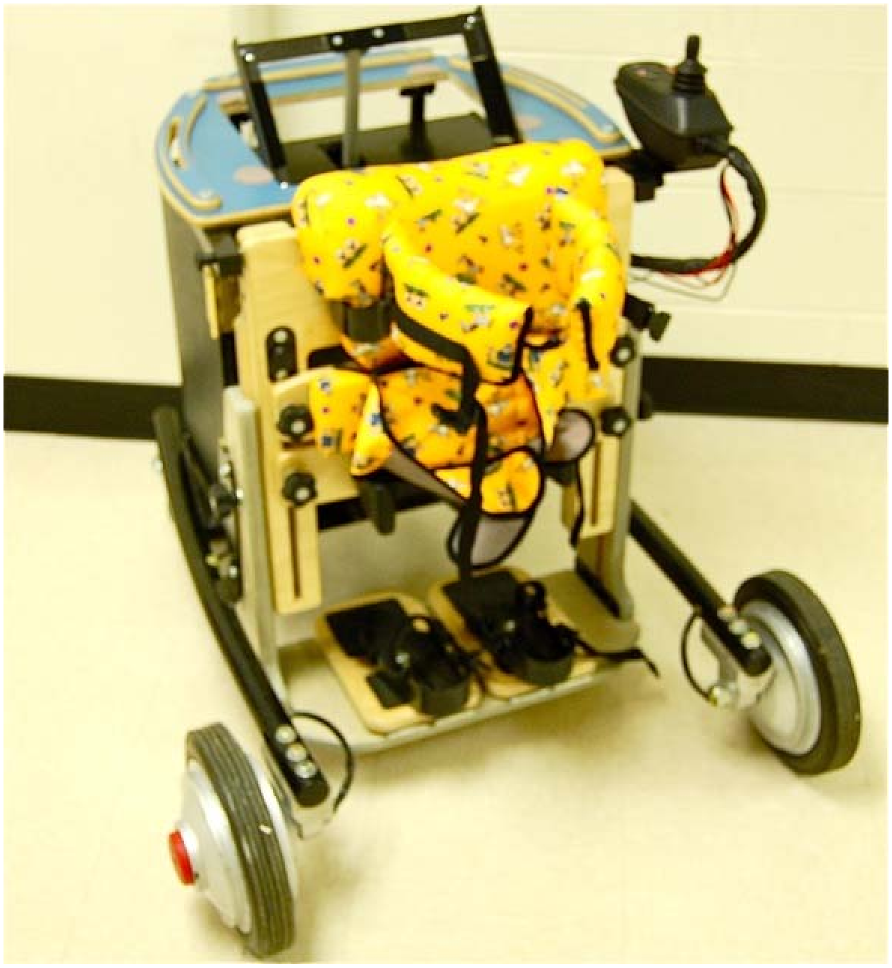

Figure 2 Motorized Prone Stander with Touchscreen Computer Device

As shown in Fig. 2, the project can be divided into the following major sections:

(A) Prone Stander
(B) Motors, Controllers, and Tires
(C) Batteries and a Charger
(D) Touch Screen Computer
(E) Software/Games
(F) Fabrication

Initially, at the parent's suggestion, the plan was to purchase a prone stander identical to the child's current prone stander (a Lecky Penguin Stander) and modify it so it would be motorized. However, it was expected that the child would use it for several years. Unfortunately, this particular prone stander was made out of wood. It was aesthetically pleasing and very well made, and wood would have been easy to work with. Additionally, when researching the prone stander, it was discovered that this particular company made models for larger children. However, adding two motors, at least one battery, and a growing child, the team was very concerned that the wooden prone stander would not have been able to handle the weight. The team contacted the family and told them their concerns. The family understood, and had no problem with a different prone stander. A search for a new prone stander was soon underway. The team found a suitable prone stander with a metal frame rather quickly and ordered it (Leckey Prone Stander Size 1).

Initially, the team thought that finding a motor controller and motors would be fairly easy. Motorized wheel chairs are very common. Unfortunately this was not the case. There were several constraints associated with the motors. The total width of the stander with the motors must be narrow enough to fit through a standard Americans with Disabilities Act (ADA) door. For safety reasons, the motors needed to have electromagnetic brakes which lock when there is no power applied. There needed to be manual brake releases so the prone stander could be pushed. They also needed to have variable speeds. Several different brands of acceptable motors were easily found. Several different brands of acceptable controllers were easily found. Unfortunately, the brands of motors did match up with the brands of controllers. Most likely, it would have been a lot of work to make the controllers and motors compatible. Fortunately, the team was persistent and came across a company that sold complete kits to make wheelchairs motorized. The kits included both motors and controllers. The motors were brushless hub motors. The company was Goldenmotor, based in China. The team was very concerned about ordering parts from China. Concerns included shipping costs, customs issues and delays, and shipping time. However, the concerns turned out to be unwarranted. Two sets of motors were ordered along with two joystick motor controllers. Extras were ordered in case a motor or controller was bad, a motor or controller was damaged in shipping, and some other unfortunate circumstance. This way, there was no reason to make another order from China. The second set also allowed students to work independently and simultaneously.

The motors and controllers arrived just fine. But that led to the next problem. The motors need to have tires. The motors are hub motors and were intended to have spoke tires. The team visited several local bicycle and ATV shops in the area and soon realized that spoke tires would have raised the prone stander to unacceptable heights. The team came across a rubber tire whose dimensions matched the hub motor. The tires were ordered. But when the tires arrived, the team realized that tires' inside diameter was about 1" too small for the hub. Carefully using a CNC mill, the tire was milled to the appropriate diameter. The tire was then heated to ease stretching over it the hub. However, when trying to place the tire on the hub, the tire ripped apart. The combination of milling the rubber tire and heating it so it would be more pliable caused to tire to shred. The team continued to look for tires. The team found a wheel barrow tire that had the perfect diameter and width. The tire was heat treated, and after a few attempts, the tire was on the motor hub.

The motors required 24 volts. The choice was between one 24 volt battery or two 12 volt batteries in series. It was quickly decided that two 12 volt batteries in series would be more appropriate. The 12 volt batteries would be easy to replace in the future. It would be easier to balance or center the batteries on each side. A 24 volt deep cycle battery charger was also purchased.

The touch screen computer solution came in a most serendipitous occasion. A local blood drive was taking place on the UTM campus. The team noticed that the workers were using touch screen computers to take the blood donor's information. The design team questioned them about the computers. Who made them? Were they happy with them? Did they work as expected? Were they robust? The blood drive workers were very cooperative and gave the computers high marks. The team decided that this was the touch screen computer that they wanted for the project. The touch screen was a Sahara i200.

This team also decided to use Visual Basic in the Microsoft Visual Studio. Four educational activities were developed. They are described below.

Paint Application – The child selects a paint color, and simply draws something on the screen. It includes sound effects and an encouraging cartoon mascot who guides the child as they use the program.

Barn Yard Sounds Application – Six cartoon animals are shown on the left and right sides of the computer screen. When one of the animals is selected, it moves to the center of the screen, makes the appropriate sound for the chosen animal, and then moves back the side of the screen. The process is repeated for the other animals.

Story Teller Application – This application tells a story. It includes animations, audio, and lyrics. As the story is read, the words at the bottom of the screen change from white to red.

Coloring Book Application – This application includes eight pages of objects that can be colored with eight different colors. The child simply picks a section of the object, selects a particular color, and the section is colored.

The prone stander that was purchased was heavily modified. The prone stander originally allowed multiple prone positions/angles. The parent's stated that the child only needed the vertical position. The prone angle adjustment was removed. The prone stander also had a tray table which was adjustable. This adjustment was also unnecessary. The adjustment mechanism for the tray table was removed. Removing both adjustment mechanisms allowed room for a battery box to be built and placed on the front of the prone stander. The motors were placed on the rear of the prone stander. This required the design of some new motor mounts but was quite straightforward. The motor controller was placed on the right side of the stander. A square was cut out of the tray table so that the touch screen would fit flush, and new supports were made for the tray. The two batteries and the battery charger were placed inside a battery box. The battery box had doors on both the left and right side for easy access to the batteries. The original front casters on the prone stander were unsuitable, but finding casters that would support the two batteries and battery charger was a relatively easy process.

4. Conclusion

The paper discussed designing assistive technology devices for families with disabled children. Six engineering students worked on the projects for two semesters as part of their capstone design project. Students had the opportunities to directly work with families on device specification and testing. The two projects were successful and delivered. These two devices significantly assisted the children with improved learning, communication, and accessing to daily tasks.

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References

[1] Terpenny, Janis, Robert Gao, John Ritter, Donald Fisher, and Sundar Krishnamurty, "Senior Design Projects to Aid the Disabled", *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*.

[2] Brackin, Patricia, and J. Darrell Gibson, "Capstone Design Projects: Enabling the Disabled", *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition*.

[3] May-Newman, Karen, Peter Newman, and Urban Miyares, Senior Design Projects in Assistive Technology: Opportunities for Technology Transfer, *Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition.*