CHAPTER 16
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WATERING ASSISTANT FOR KIDS WITH CEREBRAL PALSY

Designers: Stacey Pest, Quinn Dunlap, Anastasia Wengrowski, Jessica Patterson
Client Coordinator: Marliese Delgado, OTR/L; Hand in Hand, UCP of Greater Birmingham
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
Department of Biomedical Engineering
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INTRODUCTION

Hand In Hand (an affiliate of United Cerebral Palsy of Greater Birmingham) offers outreach programs for local families to facilitate the growth and development of impaired children by educating their parents to foster constant learning. Hand In Hand has a daycare facility where children can be assisted by skilled physical and occupational therapists, speech pathologists, and special instructors. Recently, a beautiful garden was donated to the facility for the children to enjoy. The faculty at Hand In Hand wanted the children, both wheelchair-bound and ambulatory, to be able to assist in the gardening process. However, the garden was inadequately designed for the children in wheelchairs to experience; the planter bed edges are too wide for the children to approach and assist with gardening.

Because people with motor disabilities have trouble getting enough exercise, horticulture therapy is a step toward activity, as it can help children develop leisure skills, participate in community activities, and gain a sense of responsibility. In order to facilitate such therapy, this design team developed watering constructs to assist wheelchair-bound children with cerebral palsy to garden at a local daycare. The major constraint in designing this apparatus was that it was adaptable for children with a range of disabilities/symptoms (GMFCS Levels IV-V) as well as a variety in children ages/sizes (2-5 years old). Marliese Delgado, a physical therapist at Hand In Hand provided a Big Red® switch, or a large button, as an easy operating mechanism for those with limited hand and arm motor function.

SUMMARY OF IMPACT

This device will allow the children at Hand In Hand with the most severe disabilities to participate in outdoor horticultural activities. This allows them to be involved in outdoor activities with the less severely disabled children of Hand in Hand, providing them with a sense of worth and accomplishment. It also provides the staff therapists with one more outside option to entertain the children on nice days.

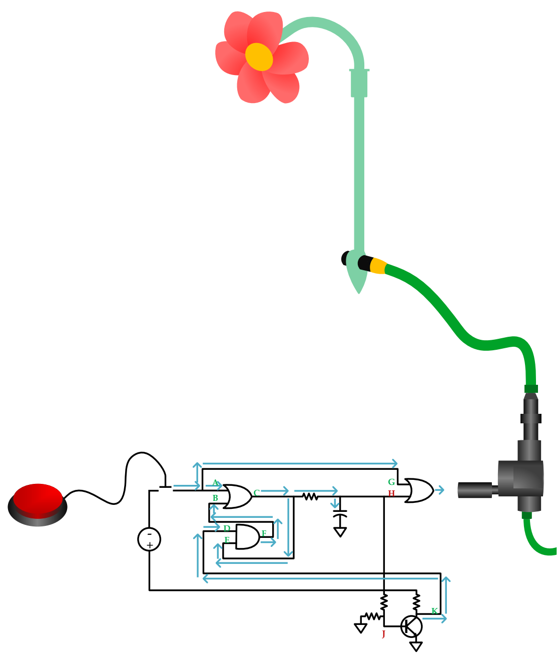

Fig. 16.1. Final circuit schematic including logic gates; the circuit links the switch to the sprinkler providing 10 second intervals of water discharge with each push of the switch.

TECHNICAL DESCRIPTION

The completed device is an interactive switch-timer-valve assembly, including a switch, a latching solenoid valve, a hose, a shower head, and a logic gate circuit timer. Once the switch is pressed, current is sent through the logic gate timer, which opens the valve. While the valve is open, the RC circuit built into the logic gate timer charges, allowing the appropriate watering time to be met (10 seconds). To account for the latching solenoid in the valve, the initial relay circuit was modified to include a logic gate circuit. As a result, the first pulse supplied by the logic circuit opened the valve, but a second pulse needed to be applied in the reverse direction to close it. Therefore, an H bridge and two LM555 timers were implemented. The H Bridge allows voltage to be applied across the valve in either direction. The two LM555 timers act more as safety mechanisms; the first LM555 accounts for an extended button push, while the second LM555 regulates the long second pulse that results in closing the valve. A hose connects the valve to the shower head, while the shower head sticks directly into the soil. An enclosure contains the logic gate circuit, as well as the valve and switch connection wires, to ensure water-tight operation. The final circuit and device schematics are shown in Figure 16.2. The total cost for the completed device was $1081.

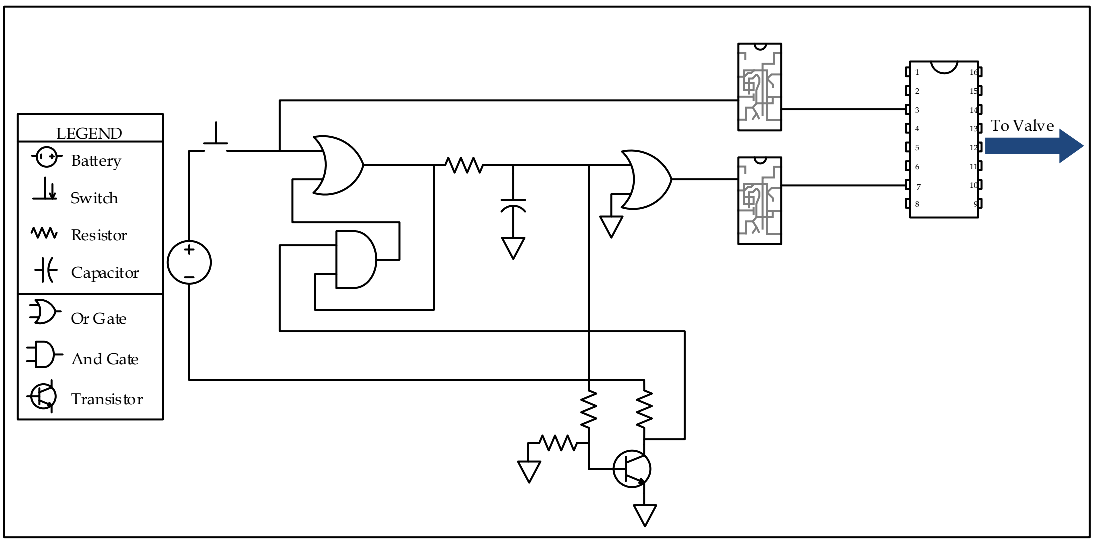

Fig.16.2. Final Device Schematics.

AN APPARATUS TO INDUCE PRIMARY BLAST INJURY IN MICE

Designers: Justin Chuang, Jose Roman, Adam Threet, Nathan Hadley
Client Coordinator: Candace Floyd, PhD, Department of Physical Medicine and Rehabilitation
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
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INTRODUCTION

Explosive blasts have been the leading cause of casualties in recent wars, such as Operation Iraqi Freedom and Operation Emerging Freedom. Fifty-nine percent of soldiers that have been exposed to explosive blasts were diagnosed with traumatic brain injury (TBI), and in 44% of these cases, only a mild TBI was actually reported. It is thought that these TBIs are caused by blast overpressure waves produced from explosions. Overpressure is the immediate rise in pressure due to the explosive blast and is the maximum peak of blast wave. Primary injuries occur when the overpressure wave reaches the body and causes direct tissue damage. The current design focused on primary blast injury, that is, the direct damage from blast overpressure wave.

Our client's main research focus is the pathobiology or progression of central nervous system (CNS) injuries. Dr. Floyd's current research involves determining the brain injury threshold of a soldier after exposure to a blast wave. The present design project provides a primary blast injury device that was cost-effective, able to produce a repeatable injury, and able to mimic a mild human battlefield blast injury in a murine (mouse) model.

SUMMARY OF IMPACT

This new device will permit our client to study how primary blasts are associated with subsequent disabilities caused by damage to the central nervous system. Operation of the final device is performed by a single operator, reducing operations costs. The apparatus is mounted on a laboratory bench or table using the included clamps and the wave absorber attached. A desired distance for the specimen restraint is chosen by moving the sliding base and set with clamps. The desired cartridge is loaded into the Hilti tool, and the tool closed. The sedated mouse is loaded into the specimen restraint and placed in the mount at the appropriate orientation. The operator, with appropriate hearing protection, pushes the Hilti tool fully forward to disengage the safety, and then pull the trigger to initiate the blast. Afterward, the specimen is removed from the restraint and placed in a recovery area. Cleaning the specimen restraint, placing a fresh cartridge in the Hilti tool, and saving the data from the oscilloscope refreshes the set-up for the next specimen. Once all the data is collected, connection to a computer allows for use of the included GUI for analysis. This GUI processes the raw data and creates graphs and analysis of the data.

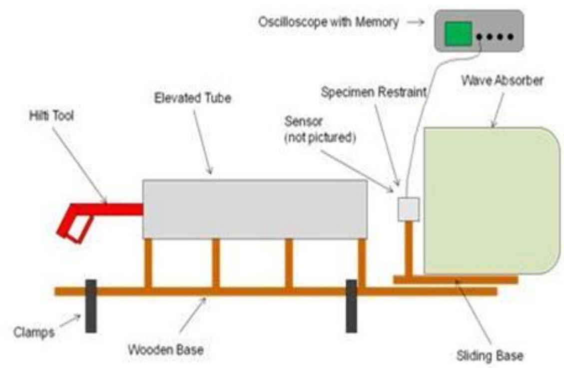

Fig.16.3. Two-Dimensional Schematic of final design listing all components.

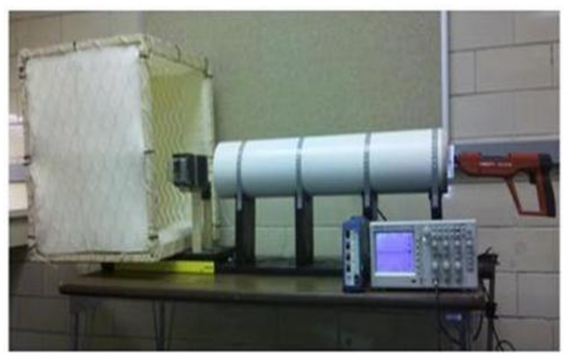

Fig. 16.4. Photograph of completed device installed in lab of Dr. Floyd.

This processed data is sufficient to characterize the parameters of the blast wave.

TECHNICAL DESCRIPTION

The completed design (Figure 16.4) consists of five subsystems: blast overpressure source, blast/shock tube, specimen restraints, pressure transducers, and rebounding wave absorber. The blast source selected was the Hilti tool, due to the very low maintenance and minimal modifications it required and its ability to produce reproducible pressures through the use of standardized charges. PVC (polyvinyl chloride) was the best alternative for the blast/shock tube. It was found to be the most cost efficient, easily manipulated, strong but lightweight, and would be the easiest to modify. The material used to construct specimen restraint was Plexiglas, due mostly to its low cost and easy manipulation. Design for specimen restraint consisted of a box to contain the specimen, while providing head isolation and stabilization. The restraint was mounted to a sliding base so that different desired peak overpressures can be achieved. The pressure transducer chosen was a PCB Piezoelectric transducer Model 101A06 is an ICP (Integrated Circuit Piezoelectric) Low-Impedance Quartz Pressure Sensor. It has a measurement range of ± 5 Volts output with a maximum pressure of 3450 kPa. It has a built in amplifier that converts high impedance charge into a low impedance voltage that is displayed on the oscilloscope, which is the final piece of the system. This device displays the graph of the wave in Volts/Time. The voltage can then be converted into standard units of pressure using tables that are readily available. The rebounding wave absorber was made up of inexpensive mattress foam surrounding a wooden cube frame covered in chicken wire. In addition, a MATLAB Graphical User Interface (GUI) was developed in order to minimize the operator's fluency in programming language. The total cost of the design was $1160.

A WHEELCHAIR TILT-COUNTER TO SUPPORT THERAPEUTIC RESEARCH OF PAIN AND CEREBRAL PALSY

Designers: George Waits, Chin Siu, Binh Vu, Russell Fung
Client Coordinator: Laura Vogtle, PhD, OTR/L, Division of Occupational Therapy
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
Department of Biomedical Engineering
University of Alabama at Birmingham
Birmingham, Alabama 35294

INTRODUCTION

This design seeks to provide enabling technology to the UAB School of Health Professions by providing a means of measuring the tilt angle of a Tilt-in-Space wheelchair used by people with cerebral palsy and other conditions. Specifically, faculty member Dr. Laura Vogtle (Occupational Therapy) studies the painful effects associated with the sedentary habits of those with motor impairments including those with advanced levels of cerebral palsy and spinal injuries. To determine whether, and the extent to which, tilting behavior affects the level of pain experienced by wheelchair users, Dr. Vogtle requested a device capable of automatically measuring and recording the time-dependent tilt angle of various tilt-in-space wheelchair models. Once constructed, the device would be used on wheelchairs at Birmingham's United Cerebral Palsy daily-care facility LINCPoint.

Fig. 16.5. Accelerometer mounted on wheelchair.

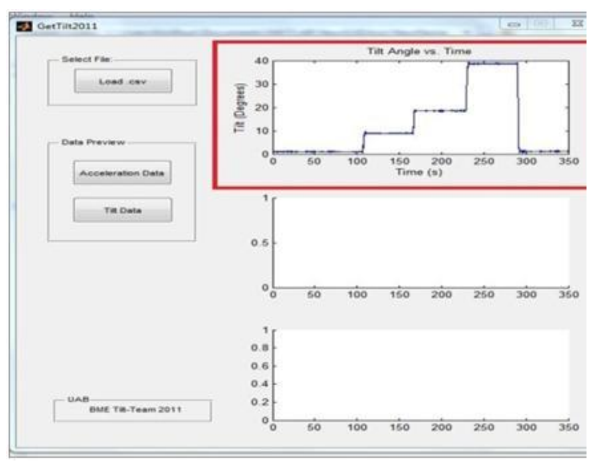

Fig. 16.6. GUI for data interpretation.

SUMMARY OF IMPACT

The tilt sensor system will be used by Dr. Vogtle and the staff at LINCPoint in order to test the tilt-pain hypothesis. This device will be used to study the tilting habits of those using wheelchairs as their primary mobility source. A self-report pain level scale will be employed as a means of associating the tilt behavior with pain data. The aim of these studies is to develop therapeutic tilting norms with the goal of reducing wheelchair-related pain.

TECHNICAL DESCRIPTION

The student team arrived at an accelerometer-based design, stored on-board the sensor, through which tilt angle and duration data are transferred to a computer via USB where data analysis is facilitated using a MATLAB guided user-interface program (Figure 16.5). The program converts acceleration data to the tilt vs. time data specified by Dr. Vogtle. A tri-axial low noise Gulf Coast X6-2 Accelerometer is mounted on the wheelchair with a bicycle mount to enable sensor alignment. The long axis (X-axis) of the sensor is mounted parallel to the ground while the sensor base is oriented perpendicular to the ground. Raw data logged by the X and Y-axes are saved in *.csv format and transferred to the computer using USB drive. To convert raw data to tilt data, a user-friendly Matlab GUI was constructed. During data processing, the raw data is divided by a constant value of 16,384, as specified by the user manual, to obtain acceleration data. Since both the X and Y axes are experiencing a change of acceleration due to tilt motion, the following equation is used to convert acceleration data to tilt angle: $\theta=\arctan(g_x / g_y)$, where g_x and g_y are the accelerations due to gravity in the x and y sensor axes respectively, as illustrated in Figure 16.7. Tilt data is then filtered by a stationary-magnitude filter and a moving average filter to reduce noise caused by translational motion. Finally, the GUI exports the data into an EXCEL spreadsheet *.xls providing the client with tilt data in degrees corresponding with the time in seconds.

The final cost of the device was just under $160.

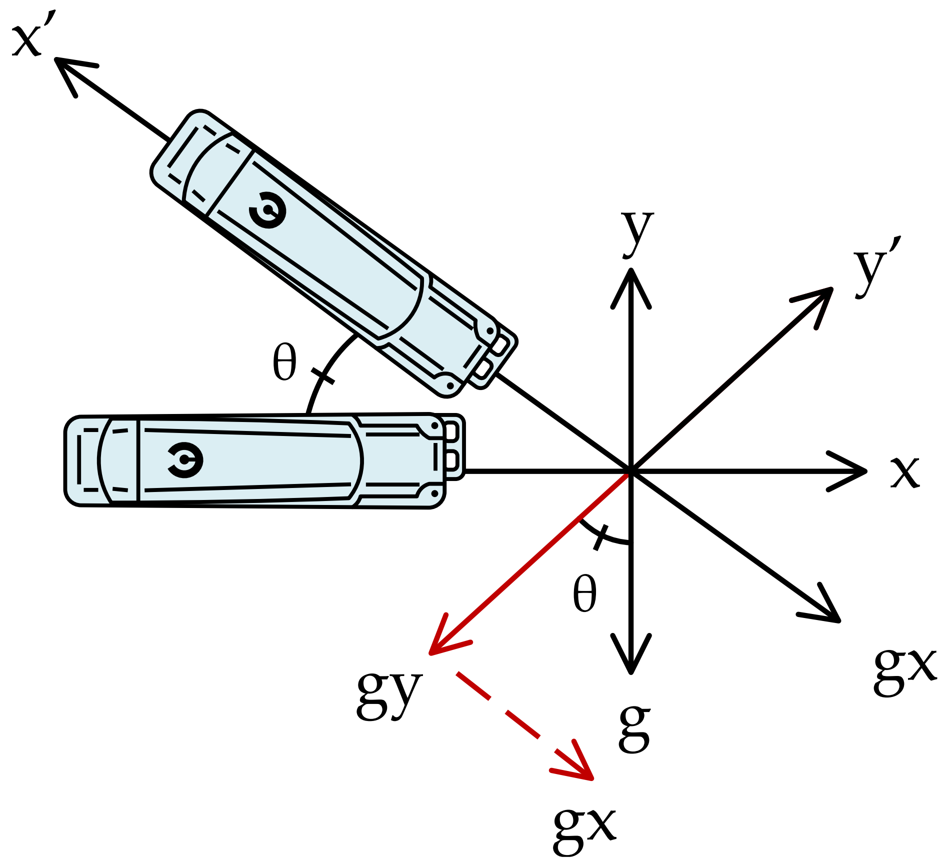

Fig.16.7. Sensor orientation and determination of tilt angle based on acceleration components.

A BUBBLE TOWER FOR ADULTS WITH CEREBRAL PALSY

Designers: Ron Baxter, Charles Moore, Joseph Pak
Client Coordinator: Jessica Morrow, PT, LINCPoint, UCP of Greater Birmingham
Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD
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INTRODUCTION

LINCPoint is a non-profit organization that provides a variety of opportunities to patients ranging from treatment to a paid work experience. Patients with more severe developmental disorders, those most likely to take advantage of aural-visual stimulatory devices, are cared for by attending personnel and are provided everything from physical therapy and skill training to craft projects and other stimulatory tasks designed to improve quality of life. Patients with cerebral palsy (CP) can display sensation, perception, concept formation, and symbol formulation deficiencies, which can greatly inhibit learning, reasoning, and general cognitive function. Sensory stimulation is one of the older treatment methods used in the care of patients with CP and studies indicate that combined aural-visual treatment results in improved motor control for CP patient motor function.

Jessica Morrow, physical therapist at LINCPoint, requested an improved bubble tower based on a previous design for users suffering from a variety of mental and physical abnormalities that limit their range of muscle control. The design constraints included integrating the bubble tower with the LINC Point Multi-Sensory Room. There would be a base that will sit in a corner of the room with enough height for users to sit. A pad must be present on the top of the base on which users can sit. The tower itself must be a clear cylinder with dimensions of a 10" outer diameter and 5-7 foot height. There must be an option of giving a user of the tower control of forming a "burst" of bubbles by pressing a switch held by the user. Lights must be present within the bubble tower and within a bundle of fiber optic cables that can be held and must offer an array of changing colors.

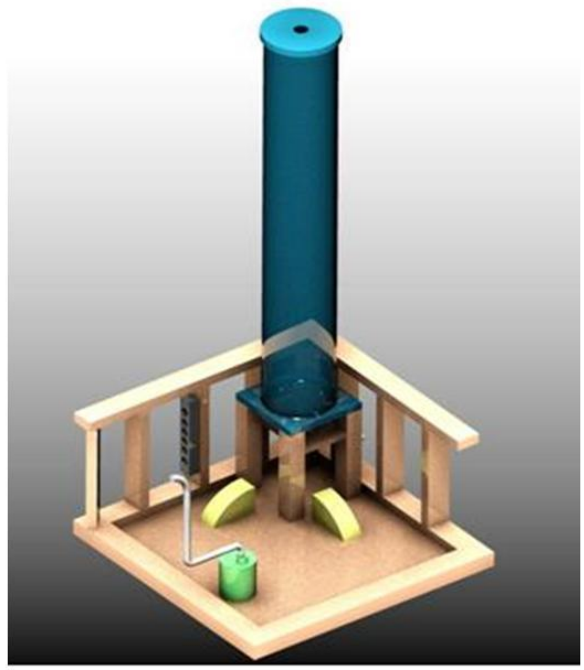

Fig. 16.8. CAD drawing of the bubble tower, which contains two pumps for generating bubbles lit by multi-colored LED lights, which are controlled by persons with disabilities.

SUMMARY OF IMPACT

According to physical therapist Mr. Billy Ronilo, before an insurance company is willing to provide powered wheelchairs to children with cerebral palsy (CP), the children must demonstrate their ability to use the wheelchair effectively. The completed device allows Mr. Ronilo to more efficiently and effectively use his time in traveling to clients' houses to train their children disabilities to drive the wheelchair.

TECHNICAL DESCRIPTION

The major components are the (a) base, (b) tower, and (c) the electrical components (lights, pumps, IR repeater, and power strips). The bubble tower functions as a tower filled with water with air bubbles produced at the bottom via air pumps. Check valves are used to prevent water backflow into the air pumps. Illumination of the tower is produced by 4 LED lights with remote controlled synchronized color changing capability. The base dimensions are 40in x 40in x 20in, and a tube height of 5ft and diameter of 10in. The base frame is made with 2in x 4in studs along a 2in x 4in outline, secured with braces, with a plywood top and bottom. It boasts an upholstered and padded seating area and an internal compartment in the base housing the electrical components, including the power strips (2), LED lights (4), tower support posts (4), air pumps (2), base support posts (3), base roof runners (3), infrared repeater (1), infrared receiver (1), and infrared transmitters (4). The tower has a Plexiglass bottom with access ports for the air pump tubing, and drainage system, and the tube has a removable Plexiglass lid with an air pressure release port. The drainage system, constructed of PVC, has a garden hose adapter that allows attachment with a standard garden hose to allow easy drainage.

A CAD rendering of the final device is shown in Figure 16.8. The total cost was just over $1,500.

BAMBOO CRUTCHES FOR ZAMBIANS WITH DISABILITIES

Designers: 20 teams of 4-5 sophomore engineering students = 98 students
Client Coordinator: Alan Eberhardt, PhD
Supervising Professor: Alan Eberhardt, PhD
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INTRODUCTION

EGR 200, Introduction to Engineering Design, provides transfer students at the University of Alabama at Birmingham an introductory engineering experience, including a 5-week design project. This year, the authors led a project that involved the design of crutches for use in a developing nation that featured the use of "appropriate technology" regarding materials and construction techniques. The target country was Zambia, Africa, which is one of the poorest countries in the world. In Zambia, the majority of the population lives on less than $2 USD per day. Lack of medical facilities and doctors leads to many serious health issues. Infection often leads to amputation, creating a need for low cost crutches.

The assignment was to design and construct bamboo crutches for use by an average man, woman or child (6-10 years old) in Zambia. What made this project unique were the design constraints, which included the use of sustainable materials available to Zambians (bamboo, sisal twine, wood glue, leather and burlap). The use of power tools was also forbidden, since it is unclear whether the SIFAT Center will have a consistent source of electricity. The overall goal was to provide crutch designs that could be translated to the SIFAT Center for mass production and use by local Zambians. In the first related lectures, the students were introduced to the design problem, EWB and SIFAT, and the associated issues of sustainability in developing countries like Zambia. Next, they were exposed to concepts in engineering design such as engineering sketches & computer aided drawing (CAD, Pro-E, Needham, MA), statics & free body diagrams, column buckling, stress analysis, and material selection and analysis using the CES Edupak software (Granta, Cambridge, UK). The students were required to build the devices themselves, and therefore attended a general lab safety seminar and subsequently spent three class periods working on their projects in the School of Engineering (SOE) Design Lab. The students were required to present their final projects as oral presentations (using PowerPoint) and to submit a final written report, both of which were done as a team.

Fig. 16.9. A winning design and associated team members at the final presentation.

Fig. 16.10. Example completed crutch designs.

SUMMARY OF IMPACT

The UAB section of Engineers without Borders (EWB) is currently involved in the development of a SIFAT (Servants in Faith & Technology) Center in Zambia. The purpose of the SIFAT Center is to provide training for persons interested in making a difference in the lives of poor people around the world. Last year a team of Mechanical Engineering senior design students developed a bamboo wheelchair and brought the design to Zambia with the EWB, in hopes of developing a sustainable manufacturing center within the walls of the developing SIFAT Center. This year, we hoped to extend those efforts by adding bamboo crutch designs.

The overall design project and educational experience was an overwhelming success. Based on the IDEA surveys, the majority of students worked well in their assigned teams, the SOE Design Lab facilities were adequate and the restriction to use only hand tools resulted in a safe and satisfying design experience. Feedback from the design experience was provided by the students through the IDEA course surveys. Students were also encouraged to provide comments related to their overall experience with the design activities, working in a team, and their levels of confidence and enthusiasm to continue in engineering.

TECHNICAL DESCRIPTION

Overall, 19 different crutch designs were completed using the appropriate technologies proposed. Many included the bonus feature of height adjustability. Examples of completed crutches are shown in Figure 16.10. Their final reports and presentations included engineering sketches and Pro-E drawings, free body diagrams for column buckling and stress analysis, as well as material analysis using the CES Edupak software.

The total cost of the designs associated with this course was roughly $600.

BAMBOO TRANS-TIBIAL PROSTHESES FOR ZAMBIANS WITH DISABILITIES

Designers: Four teams of three students = 12 freshman Science and Technology Honors students
Client Coordinator: Alan Eberhardt, PhD
Supervising Professor: Alan Eberhardt, PhD
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Birmingham, Alabama 35294

INTRODUCTION

STH 201, Research Approaches in Engineering, is a course for freshmen in the Science and Technology Honors program, which involves an introduction to the principles of engineering mechanics and materials, with an emphasis on engineering design. The students are introduced to computer-aided drawing (CAD), computer-aided manufacturing (CAM), machining processes, mechanical testing and failure analysis using light and scanning electron microscopy. This year, a 5 week design activity was included, where 4 teams of three students worked to develop prostheses for a trans-tibial amputee, using sustainable materials found in the country of Zambia. The assignment was to design and construct bamboo prostheses for use by an average man, woman or child (6-10 years old) in Zambia, who had suffered from a trans-tibial amputation. The design constraints included the use of sustainable materials available to Zambians (bamboo, sisal twine, wood glue, leather and burlap) and the use of power tools was also forbidden. The overall goal was to provide devices that could be translated to the developing SIFAT Center for mass production and used by local Zambians. In the first related lectures, the students were introduced to the design problem, EWB and SIFAT, and the associated issues of sustainability in developing countries like Zambia. Next, they were exposed to concepts in engineering design including statics & free body diagrams, column buckling, stress analysis, and material selection and analysis using the CES Edupak software (Granta, Cambridge, UK). The students were required to present their final projects as oral presentations.

SUMMARY OF IMPACT

These projects were also developed along with the UAB section of Engineers without Borders (EWB) and the development of a SIFAT Center in Zambia. With this project, we hoped to extend the offerings to include lower limb prosthesis designs.

The overall design project and educational experience was an overwhelming success. Based on the end-of-the-term surveys, the majority of students worked well in their assigned teams, and were extremely pleased with the experience and felt empowered to continue in their respective engineering disciplines.

TECHNICAL DESCRIPTION

Overall, four different prosthesis designs were completed, as shown in Figure 16.12. The final reports and presentations included engineering sketches and Pro-E drawings, free body diagrams for stress analysis, finite element simulations, as well as material analysis using the CES Edupak software. The total cost of these projects was roughly $200.

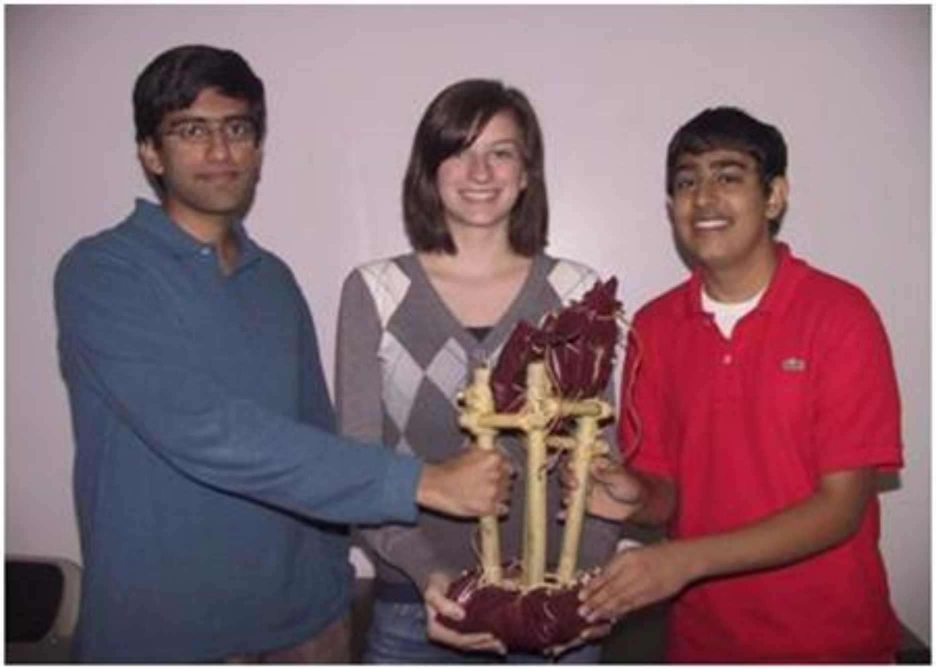

Fig. 16.11. Completed prosthesis design and team.

Fig. 16.12. Completed trans-tibial prosthesis designs.