2006-62: HUMANITARIAN DESIGN PROJECTS: HELPING CHILDREN WITH CEREBRAL PALSY

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Humanitarian Design Projects:
Helping Children with Cerebral Palsy

Introduction

The fundamental role of engineers is to serve society, and the most important ingredient of any society is the people. However, in the unfortunately chaotic and hectic lifestyles of the 21st century this fundamental role is often lost in the mists of professional practice when an engineer is required to design a nominally mundane item like a door handle for the next generation of automobiles. A profoundly meaningful and very effective way of educating engineering students, which exposes them to the societal service traditionally offered by professional engineers, is to utilize senior level humanitarian design projects. Such projects of experiential learning immerse student teams in complicated tasks that ultimately help people less fortunate than themselves.

Since 1998 the Design Program in the Department of Mechanical Engineering at Michigan State University has incorporated a series of humanitarian projects in the industrially-funded capstone projects class. During the past two years, four humanitarian projects have focused on the design, fabrication, and testing of mobility devices for children with cerebral palsy. These demanding projects have been very successful in providing our students with an outstanding engineering experience, providing the department with significant good-citizenship publicity, and, most important of all, improving the life of numerous children.

Service learning has certainly become one of the most innovative aspects to engineering education. One such example is the EPICS program at Purdue, which involves the volunteer work of engineering students in the community[1]. Another example is the Humanitarian Engineering Program, which is sponsored by the Hewlett Foundation, at the Colorado School of Mines[2]. The New Engineer Program at the University of Dayton[3] involves student teams in the conceptual designs of bicycles for different users and applications.

This paper shares our experiences in the development and implementation of these projects. The logistics of these projects is discussed, in addition to identifying potential projects and customers, the necessary resources, how to identify qualified students and faculty, and finally issues concerning project management. Each project will be presented in some detail including the technical and logistical challenges faced by the student design teams. The paper concludes with some final observations and discussion on the publicity and visibility aspects of humanitarian projects.

Project Logistics

These humanitarian projects are undertaken by teams of senior-level mechanical engineering students registered in the capstone design course ME 481, Mechanical Engineering Design Projects, for a team of senior-level mechanical engineering students. Most of the projects are industrially-based in this course with the student team working on a funded project. However, each semester, at least one project is humanitarian-based where the student team is challenged to make a difference in the lives of people that are less fortunate than themselves. Such projects require considerable entrepreneurial spirit, inventiveness, and, of course, considerable innovation because they lack the dedicated support of a commercial enterprise; a manufacturer. The first of these humanitarian projects was undertaken in 1998 and the early development of these projects is documented in [4].

About three years ago these projects began to focus on children with cerebral palsy. Cerebral palsy is a neuro-muscular disorder that limits the coordination of the brain to different muscles in the body. It is a condition that affects thousands of children in the United States. The condition manifests itself in a variety of forms and affects children in many different ways. It has been determined that the children's quality of life can be greatly enhanced through physical and occupational therapy. Mobility devices prove to be an excellent tool for these therapies and they are also ideal design projects for mechanical engineering students. Because of the great variability in the medical condition, each child will have unique needs for the design of a mobility device.

The authors have discovered several ways of identifying children or programs that would benefit from the creation of a mobility device. Many large school districts have magnet schools designed for children with physical disabilities. In the Lansing School District there are two such schools: North Elementary School is equipped to handle children with normal cognitive abilities who have physical disabilities such as cerebral palsy, while the Beekman Center handles children with both cognitive and physical disabilities. The authors have also utilized the children's physical therapy center at a local hospital to help identify children with special needs. Once a program such as this is established, parents or organizations will frequently approach the department's program coordinator directly to seek help.

Significant resources are required in order to successfully complete these projects. The number one requirement is to have a student team and faculty advisor who are committed to the project and are willing to invest a large amount of time to ensure that the project reaches fruition. A requirement of the ME 481 course is that student teams must create a written proposal in which they compete against other design teams for permission to work on a project of their choice from the long list of projects offered to the class. Two of the authors, through their roles in the department as coordinator of the design program and associate chair for the undergraduate program, have a comprehensive knowledge of most students in the program. Consequently this detailed knowledge of each student's abilities ensures that students with the desired attributes serve on the humanitarian teams. In a similar fashion, the faculty advisor is selected.

A budget of approximately $1000 is needed for the materials and cycle accessories (chains, brakes, helmet, etc.). Furthermore, the team should be encouraged to minimize expenditures by prospecting for donations from commercial enterprises, or discounts of materials and cycle accessories from local bike shops. These off-campus interactions involving commercial activities are another valuable experience for our students. At Michigan State University, we have been very fortunate to recently attract the attention of the Shell Oil Company to our humanitarian projects. Consequently, Shell Oil now provides the Design Program with a significant donation each academic year to support these projects. The last critical resource is a fabrication facility. This facility must contain the standard array of machine tools, welding facilities, and a skilled technician who can guide the students. Arrangements must be made to allow the team access to the shop beyond the normal working hours of 8:00am to 5:00pm to accommodate schedule conflicts associated with other classes. Though it is expected that the team will do most of the manufacturing tasks themselves, technician support to perform functions that the team is not qualified to undertake, such as the welding of thin tubes, must be available. For these functions, the team works directly with the technician and orally communicates the required design information.

Project Management

A crucial component in the management of these projects is the weekly meeting between the members of the student team and the academic advisor. The first of these meetings is conducted by the academic advisor. The team is provided with an agenda and the format of the weekly meetings is established. At this meeting it is emphasized that the humanitarian project is significantly different from an industrially-sponsored project, in that a final device, not just a first prototype, is required at the end of the 15 week semester. This requires an acceleration of the design and analysis phase, so that there is sufficient time to manufacture and refine the device.

Three team positions are identified: liaison, recorder, and budget director. The liaison provides the communication conduit linking the customer and the design team. Furthermore, the liaison facilitates all communication with the customer, which includes the weekly email updates and scheduling site visits. The recorder takes minutes at all team meetings, documents the activities of the team both in writing and in photographic imagery, and maintains all of the team documentation during the design process. It is the responsibility of the budget director to monitor the expenses of the project, handle reimbursements, and develop a project budget that will be approved by the academic advisor and design program coordinator.

Since the manufacturing component of the project is so intensive, it requires vigorous and meticulous management. The team must develop a manufacturing Gantt chart. It must track critical time paths, including time to acquire materials and to coordinate access for skilled technician support. Finally, the students must balance their responsibilities to the humanitarian team with their responsibilities in other courses. For further reading on the management of Service Learning projects the reader should consult Chapter 6 of the book by Lima and Oakes[5].

The Projects

In each of the past four semesters a humanitarian project was undertaken whose focus was a mobility device for children with cerebral palsy. These projects and their teams are shown in Table 1.

North Elementary School: Reaching Above and Beyond

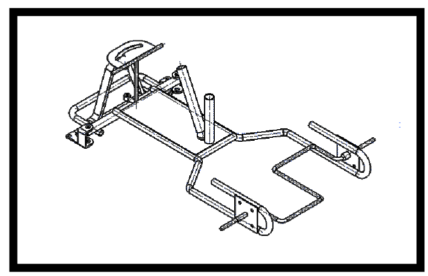
This was the first of the humanitarian projects that focused on helping children with cerebral palsy. It was also the first of the humanitarian projects documented in reference [1] that was not devoted to a single child, but to a group of children served by a physical therapy laboratory. The project involved designing and producing an exercise cycle for children ages 5 to 12, weighing approximately 35 to 70 pounds, with a medical diagnosis of Spastic Diplegia Cerebral Palsy. The team very quickly identified the critical design features for such a cycle: steering, seating, locomotion by pedaling, and aesthetics. The team built three complete system prototypes and several component prototypes. In their synthesis stage the team made considerable use of design by analogy. Some examples of this are shown in Figure 1.

Figure 1 Design by Analogy for the Reaching Above and Beyond Cycle I

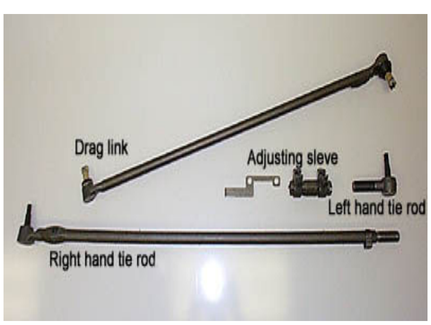
Honda CBR 600RR

Seating and Aesthetics

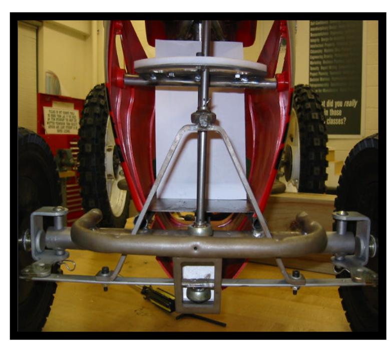
Super Monaco Kettcar



Chassis



Ford Bronco Steering



Steering System

Table 1 Humanitarian Projects

Project Title	Team	Customer
Reaching Above and Beyond	Katie Hartrick Boris Lester Sumedh Mokashi Marc Ruiz	Henry North Elementary School: Physical Therapy Laboratory
North Elementary Special Needs Cycle	Laurie Emerson Neal Koenig Kelly Stahley Jeff Staniszewski Tim Strand	Henry North Elementary School: Physical Therapy Laboratory
Marco's Wheels	Matthew Ashmore Gregory Gartland Ryan Staudacher Adam Zemke	Marco, his mothers, and the children physical therapy staff at Sparrow Hospital
Wheels to Move	Kevin Douglas Nicholas LaPlaca Nicholas Periat Saleel Pradhan	Physical therapy staff at the Beekman Center

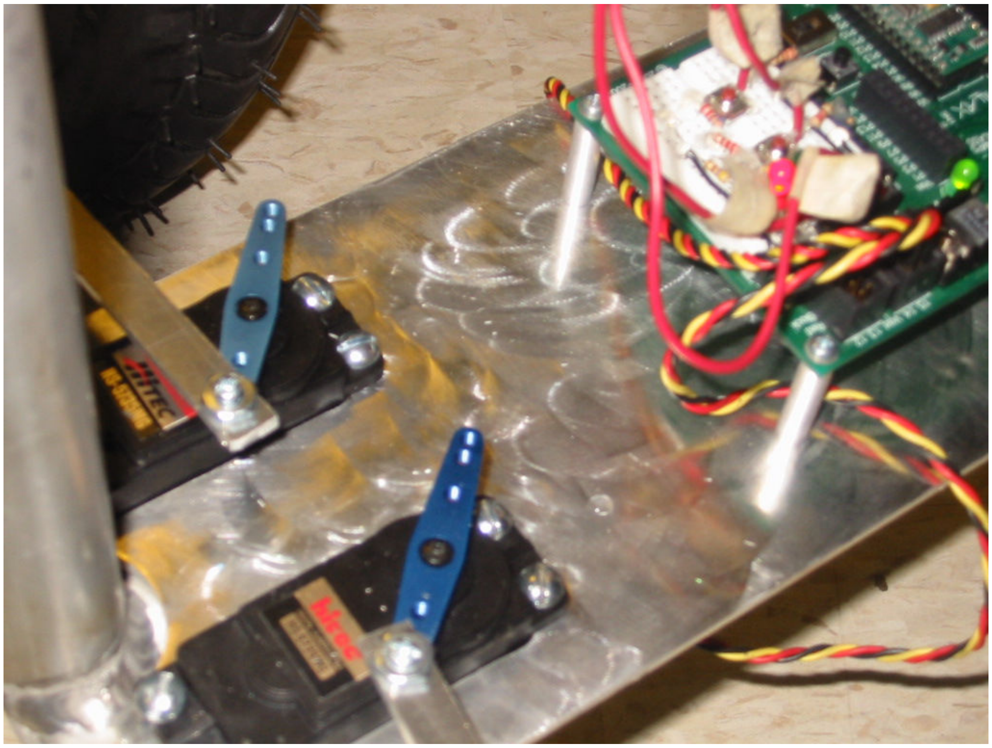
The final cycle is shown in Fig. 2. The majority of the design specifications were satisfied. The cycle certainly had appealing aesthetics, sufficient adjustability for different children, and an effective pedaling system. The mechanical steering system worked well for children with mild disabilities, but those children with more severe disabilities found it exceptionally hard to use. The seating also proved less than adequate. The concept of the leaning forward posture for the children was recommended by the physical therapy staff at North Elementary, but most of the children found it very uncomfortable.

North Elementary School: Special Needs Cycle

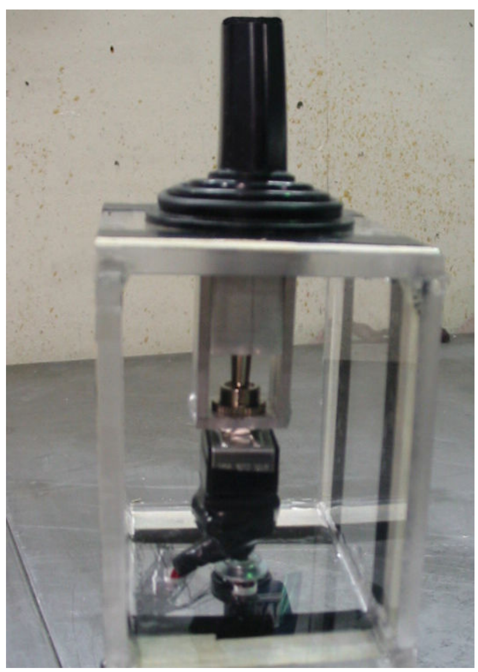
To address the steering difficulties for children with severe disabilities, a second cycle was designed and built for North Elementary School. Very quickly the team identified the need to develop an electromechanical steering system. Three design issues were identified by the team: electronic steering, joystick control, and adjustable positioning for rider preference. The final steering system, with components shown in Fig. 3, consisted of two *Hitec* digital servo motors, one C programming board, two LED's, two push buttons, one momentary double-pull double-throw switch, and several resistors. These components and the Basic Stamp programming language control the two front wheels via two DC servo motors, which are in turn controlled by the momentary switch. When the system is activated and the switch is pressed to the left, a green LED will illuminate and the servo motors will rotate to the left. Likewise, when the system is active and the switch is pressed to the right, a red LED will also illuminate and the servo motors will rotate to the right. The two servo motors are mounted in the center of the chassis in line with the front wheels. The wheels are programmed to rotate between 25^{o} and 175^{o}. Ackerman geometry was used with the programming to achieve a tighter steering system. When the switch is engaged in the maximum direction, the inner wheel radius is 5^{o} smaller than the outer wheel radius, yielding a sharper turn.

Figure 2 Reaching Above and Beyond Cycle

Figure 3 Electromechanical Steering Components



DC servo motors mounted on chassis



Mechanical Joystick

The momentary switch allows the rider to select the angle in which to steer without having to hold the position on the joystick.

In order to make the power supply easy for the physical therapist to operate, a quick-change battery system was used. The servos require 6 volts and do not draw much current, so even small capacity batteries could power the system for a considerable amount of time. The team chose to use a 6 volt lead-acid sealed battery. The 4.5 amp hours that it provided could conceivably power the cycle for over a week. To ensure the safety of the rider and the therapist, a conditioning charger was chosen. The charger also de-sulfides the batteries to remove any risks associated with the lead-acid battery. The two batteries that the team provided ensured that the therapist always had a fully charged battery for the students.

The final cycle is shown in Fig. 4. There are some striking similarities between the two cycles for North Elementary School. Clearly the electromechanical steering design was a tremendous undertaking, so in being efficient the second team borrowed heavily from the designs of the first team. The second cycle addressed the steering needs for children with a severe disability and also improved the seating comfort.

Marco's Wheels

When this project was undertaken, Marco was a two year old with spastic quadraparetic cerebral palsy, a non-progressive neurological deficit which leads to limited ability to control muscles in all four of his limbs and his trunk. Marco had spasticity, increased muscle tone limiting strength and movement, which inhibited his ability to walk, crawl, balance, or maneuver a manual wheelchair. Marco will most probably spend his life in a wheel chair. The objective of *Marco's Wheels* Design Team was to create a mobility device to facilitate Marco's independence and emotional development, through the ability to interact with his environment autonomously. Hence, this project was more for occupational therapy than physical therapy. In the end the team designed and built a small electric car for Marco and this machine is illustrated in Fig. 5.

This was the first of the humanitarian projects that was completely designed virtually. Aspects of the virtual design are shown in Fig. 6. The body, the frame, and power train were all built from scratch and were very time intensive. In fact the team spent 16-20 hours a day in the shop during the final month of the semester to complete the project. To address the perennial seating problem, the team arranged for the donation of a commercial seat, identical to what was used in Marco's stroller. As a head start on the power train and steering, the team bought a used motorized wheel chair and scavenged from it. Without a doubt, this was the most challenging humanitarian project ever undertaken by the Design Program. Furthermore it was also one of its most successful because, a year later, Marco is still touring around his neighborhood in the car!

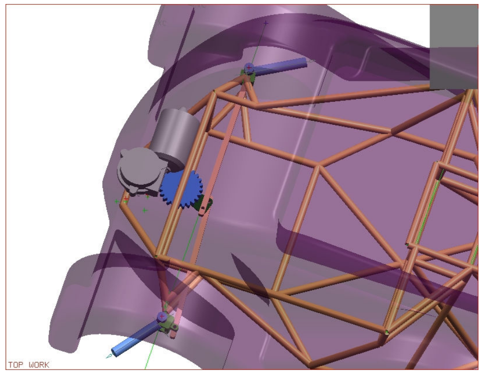
Beekman Center: Wheels to Move

For the fall semester of 2005, the Design Program was approached by the physical therapists at the Beekman Center to design and build a cycle for their students. The cycle was specifically targeted for students with cerebral palsy who have severe physical and cognitive impairments. These impaired cognitive abilities presented some different challenges for the design team. The cycle needed to have features that would allow the physical therapist more direct control of the cycle than for previous cycles. A novel approach to dual steering was developed and this is

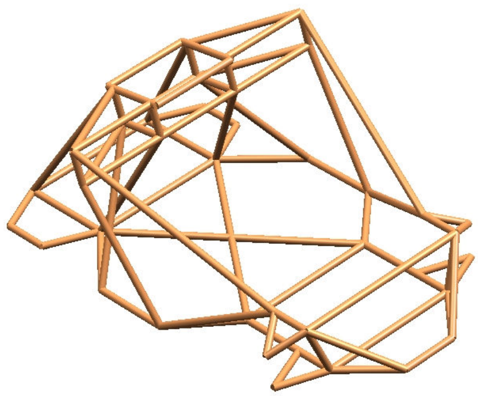
Figure 4 North Elementary Special Needs Cycle

Figure 5 Marco’s Wheels

Figure 6 Virtual Design of Marco's Wheels



Unigraphics model of steering linkage within spatial constraints



Final Chassis Design

Final Body Design.

illustrated in Fig. 7. In this innovative design, the bike would be steered by only a front-and-back arm motion using the rack and pinion steering. The U-shaped handle bar, seen in Fig. 7, is used by the children to steer the bike as they move their arms back and forth, while maintaining the same vertical plane with respect to the armrests. Thus, the sliding action of their arms will steer the bike to the desired left or right direction. In addition to the U-shaped steering mechanism for the children, the bike also possesses an additional T-shaped steering at the end of the bike that allows the physical therapist to steer the cycle. This feature enables the therapists to assume full responsibility for steering and directing the cycle while assisting the child. The final cycle is shown in Fig. 8.

Conclusions and Recommendations

During the past two years, four mobility devices for children with cerebral palsy have been designed and fabricated as humanitarian capstone design projects. They have proven to be very challenging technical projects encompassing nearly all of the conventional components of a design-build-test project: synthesis, analysis, ergonomics, manufacturing, and customer satisfaction. Beyond the technical challenges, these projects have allowed our students to develop a personal relationship with the customer and they have graduated with the conviction that they have made a significant difference to the quality of life of another human being. Furthermore, the projects, in a very tangible way, have clearly demonstrated the notion that engineers can profoundly change the lives of people. Finally, these projects have provided excellent public relations material for the design program, the department, and also the university.

Acknowledgements

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Figure 7 Dual Steering System of Wheels to Move

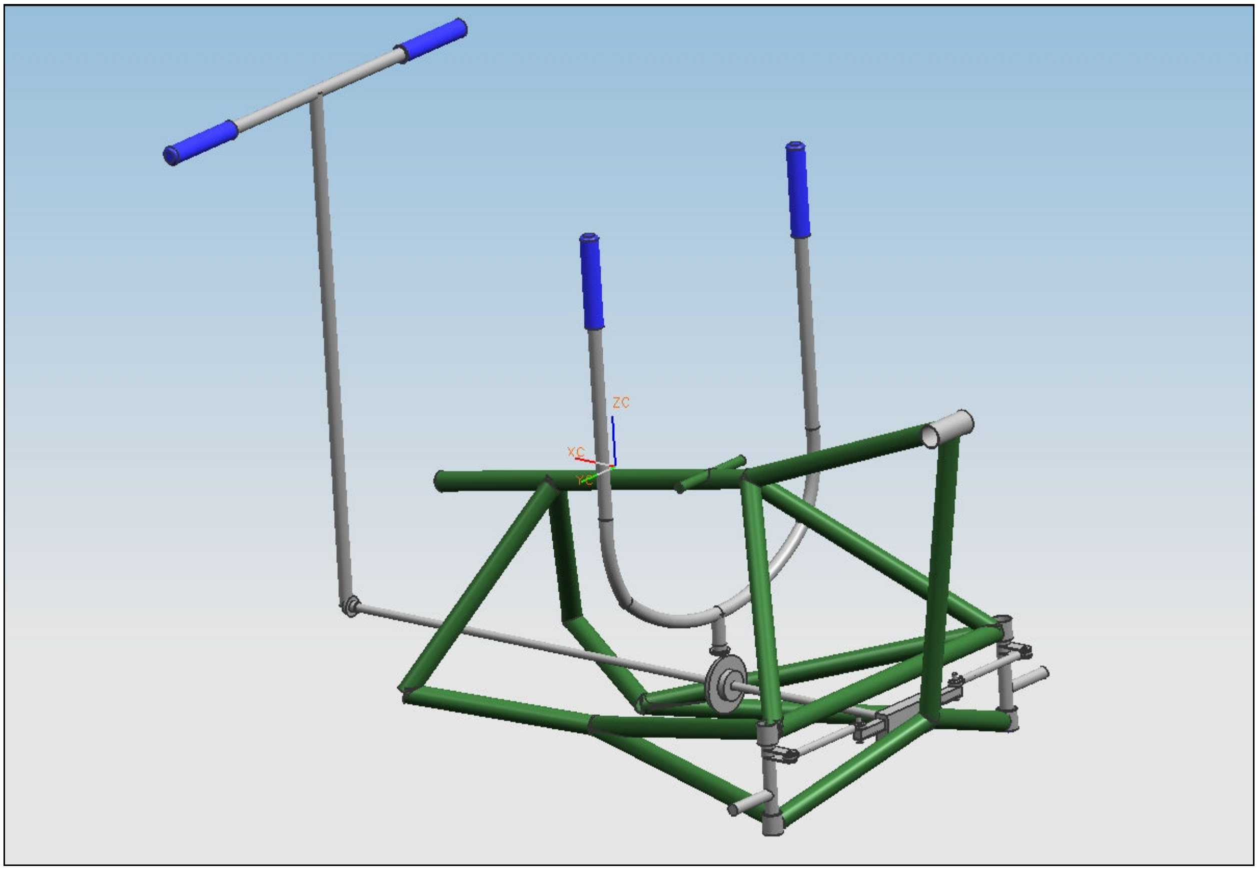

Figure 8 Wheels to Move Cycle