A Wheelchair Navigation System as a Collaborative Senior Project

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Abstract
Senior projects are common requirements in engineering technology programs. Seniors are challenged to integrate in one project the knowledge, skills and abilities learned over three plus years. Recently, the projects at Western Carolina University have ranged from wireless car alarms to three-phase motor test stations to back up energy sources for aquariums. An integral part of the Department's mission is external engagement, so the Electrical and Computer Engineering Technology faculty look for projects that can connect the WCU seniors to the community.

Recently, faculty from the College of Education and Allied Professions and the Department of Engineering and Technology identified several special needs cases where a technical innovation could improve a student's quality of life in the classroom. The initial project was the addition of a navigation system to a wheelchair. In this case, a child who is deaf-blind was given a motorized wheelchair, and a method was needed to prevent the student from running into objects in the classroom. A system was designed using four ultrasonic sensors controlled by a microcontroller board. Depending on the returned signal from the sensors, an alarm was activated to warn the student. In this design, a vibrating motor from a cell phone provided the alarm. The classroom teacher had the responsibility to teach the student to associate the vibration with the closeness to an obstacle. In the future, this classroom teacher hopes to expand the student's abilities such that the student can sense each of the four directional sensors individually.

As an electrical engineering technology senior project, the wheelchair navigation system required the WCU senior to integrate microcontrollers, sensors, programming, and power supplies and to consider the packaging issues. In addition, the collaboration required the senior to communicate with grade school teachers and the Special Education Program faculty. More importantly, this collaboration helped the senior connect his technical expertise with the needs of others and this sense of purpose energized the senior and his classmates.

Introduction
Western Carolina University (WCU) includes a College of Education and Allied Professions. Within this College's Department of Human Services, there is a Special Education Program whose mission is to prepare educators who understand child development and who use that knowledge to implement educational programs based on individual student needs. This group of educators works with student teachers and also with practicing teachers in the regional schools.

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The Western Carolina University Teacher Support Program, through offering an array of direct support services to all educators who serve students with disabilities, has led to the identification of several special needs cases where a technical innovation could improve a student's quality of life in the classroom. Seeking help with the technical solutions, the Special Education Program faculty approached the Department of Engineering and Technology and several collaborative projects were defined.

Many of the projects involve modifying existing commercial equipment for classroom use by grade school aged children. The modifications include adaptations for the smallness of the children and then further adaptations for a variety of disabilities. Two overall goals are to increase the amount of time children with disabilities can spend with their school peers, and to increase their independent learning. Preference is given to projects where the adaptations can be readily configured to additional users.

The initial project was the addition of a navigation warning system to a motorized wheelchair. A student who is deaf-blind and wheelchair bound was given a motorized wheelchair for a trial period in a classroom. The student's delight in independent movement led parents and teachers to extend the trial period. However, a method was needed to prevent the student from running into objects in the classroom. The classroom teacher concentrated on the basic go/no go instructions with the student, which required constant close supervision and feedback through physical contact. The Department of Engineering and Technology was approached to develop a feedback system to help the classroom teacher monitor and control the student's wheelchair movements.

The initial design is a system using four ultrasonic sensors controlled by a microcontroller board. The ultrasonic sensors generate a signal proportional to the distance, and, depending on the magnitude of the returned signal from the sensors, an alarm was activated to warn the student. After much discussion with the teachers, a vibrating motor from a cell phone was chosen to act as the alarm. In parallel with the electronic system development, the classroom teacher had the responsibility to teach the student to associate the vibration with closeness to an obstacle and to stop the wheelchair. Currently, the feedback is go/stop, but in the future, this teacher hopes to expand the student's abilities such that the student can sense each of the four directional sensors individually.

Relevance to Electrical Engineering Technology

The criteria for the accreditation of Electrical and Computer Engineering Technology (ECET) programs are well defined by the Technology Accreditation Commission of ABET (TAC of ABET). Indeed, graduates of baccalaureate degree programs must be able to demonstrate the ability to analyze, design, and implement electronic systems. [1]

For most ECET seniors, a project based on an electronic system is easy, and little effort is required to motivate them to build circuits. However, seniors consistently have trouble initially defining a project, and then have trouble finishing the documentation[2]. These two aspects of systems are also discussed in the TAC of ABET criteria, under Program Outcomes "a through k". In particular, programs must demonstrate that graduates have the ability to apply creativity

in the design of systems (d), an ability to function effectively on teams (e), an ability to communicate effectively (g), and an ability to understand professional, ethical and social responsibilities (i) [1].

As an ECET senior project, the wheelchair navigation system required the senior to integrate microcontrollers, sensors, programming, and power supplies and to consider the packaging issues. As at most universities, these components are studied in separate courses, and the senior project is the first opportunity for the integration of these topics and the synthesis of a system.

The collaborative nature of this project required the WCU senior to communicate with grade school teachers and the Special Education Program faculty. Communicating with non-engineering types required the senior to more fully develop his thoughts and avoid quick instant-messaging style responses. More importantly, this collaboration helped the senior connect his technical expertise with the needs of others and this sense of purpose energized the senior and his classmates. The advantages of this type of project have been well described[3,4,5].

Wheelchair Navigation System

The overall system is shown in Figure 1. This system is a separate unit, added to an existing wheelchair, with the only interconnection being the 24V battery source. The main computing engine is an 8-bit microcontroller, programmed using C-language. The microcontroller board has one analog-to-digital channel hardwired to a potentiometer, and most of the ports are available to the user through connectors. Programming of the microcontroller was done using a PC connected through a USB interface, and debugging was done using this same interface. Once the program was finalized, the microcontroller can be disconnected from the PC and act as a stand-alone unit.

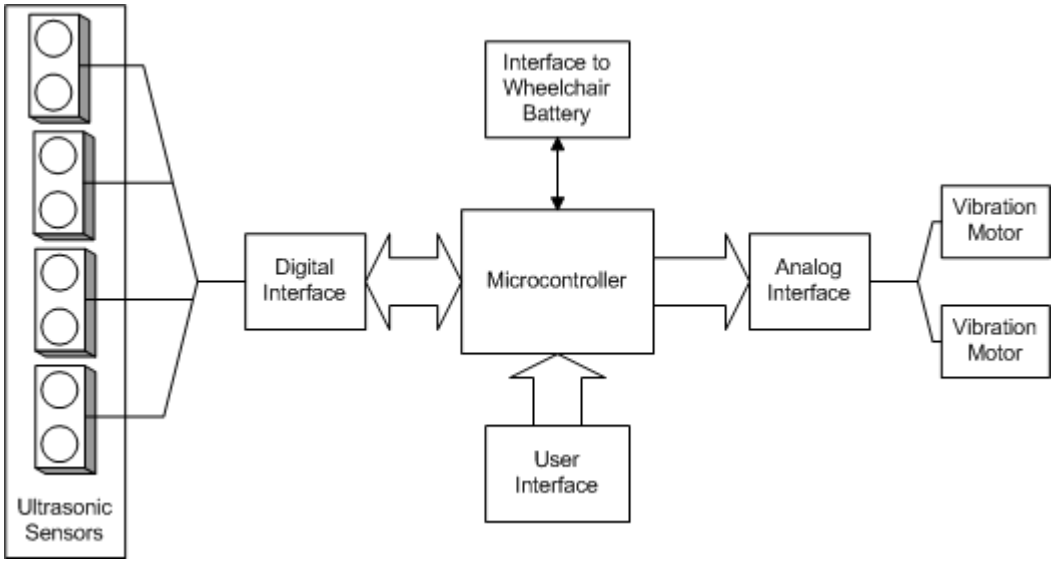

Figure 1. Wheelchair Navigation System

Circuit Operation

The ultrasonic sensors generate a short audio pulse when triggered by the microcontroller. The time to echo reception is recorded by the microcontroller. The digital event time is then compared to a setpoint, and the result of the comparison controls the vibration motors. The flowchart for this control software is shown in Figure 2. The four sensors are pulsed at 5 Hz.

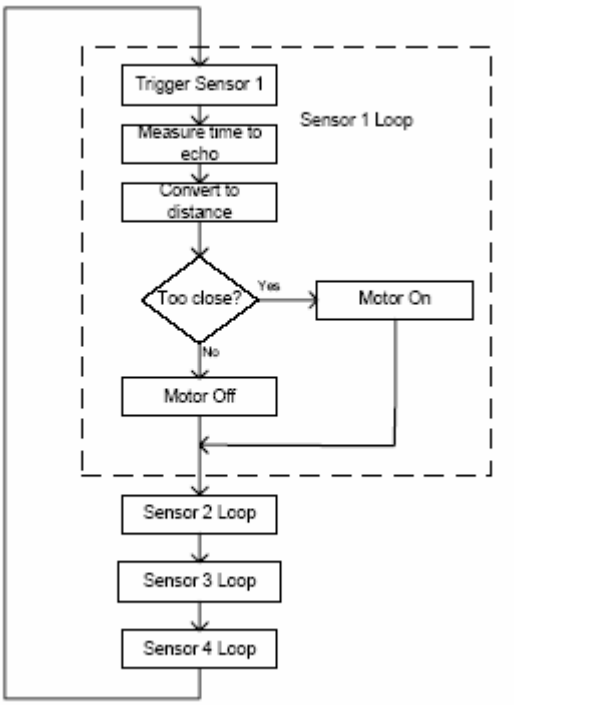

Figure 2. Flowchart for the control software.

The digital event time is related to the distance from the sensor to an object; closer objects reflect the sound waves back to the sensor quicker than far objects. The sensors here have a useful range of 15 feet. A setpoint is generated from the one A-D channel connected to a potentiometer, which allows an equivalent distance threshold to be established. When the wheelchair is "close" to an object, then a vibration motor is activated. Figure 3 shows the ultrasonic sensor and a motor, both mounted in telephone jack boxes. Using these boxes and RJ-11 connectors is a cheap and quick interconnection scheme.

The wheelchair itself is powered by two 12V batteries in series. To minimize any possible effects on the wheelchair, the designed system uses the 24V source as is. A simple connector and in-line fuse are used to connect to the wheelchair, and all voltage regulation is done on the new board.

Initially, four ultrasonic sensors were used, with each sensor controlling a vibration motor. The goal was to provide four quadrants of detection, so the student in the wheelchair could detect an object in front, back, left, and right. However, this was too complicated for the student who is deaf-blind and the system was simplified to go-no go.

Evaluation

Evaluation of individual senior projects is always a challenge. WCU seniors are given wide latitude when choosing projects and the common ground is the design process, not the designs. The primary grading emphasis is on project management, weekly progress reports, and the final oral and written presentations. For this project, the student was able to demonstrate a functioning circuit in the lab, even though it was not on a wheelchair. As discussed below, this satisfied the contract part of the senior project, but it did not satisfy the student's desire to complete the greater intent of the design project. The WCU senior's interaction with his collaborators was important, but not evaluated as part of the course grading.

Collaboration

The Teacher Support Program at WCU was initiated as a small program to help K-12 teachers use a collaborative approach to identify their problems and search for solutions. The program was designed to provide different types of assistance to special education teachers. Special education teachers often deal with the most challenging demands within the teaching profession, and are thus continually at great risk for stress, burnout, and early departure from the field. The Teacher Support Program is intended to help professionals working with special needs children to solve difficult problems, reduce stress, become more effective, and maintain career longevity[6].

Some of the problems faced by the teachers have technical solutions, and many commercial devices exist. Most existing devices, however, are designed for adults and are too expensive for usage in public schools. The goal of the collaboration discussed here is the creation of a cost effective add-on to a commercial wheelchair to allow a student who is deaf-blind to remain in a classroom with peers.

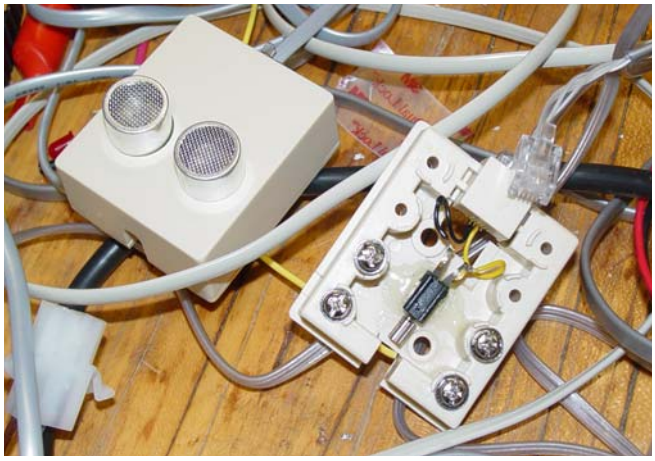

Figure 3. Ultrasonic sensor and vibration motor

There is much more to this collaboration than the specification of the inputs and outputs of a control system. Electrical and Computer ET seniors are accustomed to this type of word problem. However, in this instance, the Special Education Program faculty put human faces and hearts in the specs. Safety issues and ergonomic issues became real, as did the need to protect the privacy of the student.

One major difference with this senior project is that the navigation system is only a means to an end. The "real" project was to help a child who is deaf-blind achieve success in the classroom. This subordination of priority required the WCU senior to maintain communication with the classroom teacher and the Teacher Support Program faculty. The change from four vibration motors to one came from the classroom teacher and her efforts to teach the basic go- no go instructions. Since the teachers are not engineers, interactions with them forced the WCU senior to communicate clearly, in a language different than that of a normal ECET setting.

As with many of the ECET senior projects, this design also required the senior to collaborate with faculty and graduate students in the Engineering Technology program at WCU. This program includes the machine shops and mechanical tools required for fabrication and modification of mechanical devices. The ET group is also actively engaged with adaptive devices.

First Year Results

Introducing the child who is deaf-blind to a motorized wheelchair was enlightening for the child, his parent, and his teachers. The sense of freedom gladdened all who witnessed his movement in

the chair. However, the task of teaching the child how to control the wheelchair is taking longer than planned.

A seat cushion was modified to contain a vibration motor, connected to a simple control box with an on/off switch. The classroom teacher hoped to have the child associate the vibration with the go/no go commands. However, the academic year ended before this was accomplished.

While the classroom efforts were on-going, the WCU senior continued modifying and testing his navigation system. With the changes requested by the child's teacher, this effort continued past graduation. In fact, the first WCU senior continued working for more than a month on his own time, in order to have a working version ready for this (second) academic year.

The dedication of this WCU senior and the progress of the child led to the donation of a new wheelchair for use in the classroom this year. Another WCU senior is now working on this project, modifying the navigation system for this new wheelchair, with the goal of having it back in the classroom in January 2005.

Current Efforts

This "wheelchair project" is now well known on campus and has led to considerable interest by other university students and other groups of faculty. This year's WCU seniors requested that the Teacher Support Program faculty submit requests as soon as their school year started. Dr. Cooper-Duffy presented five projects to the class, and she and Dr. Prohn provided details on related commercial devices.

One interesting outcome of these presentations was the split in the class. Several seniors could not work on these projects as the pressure of not doing a good job was too great. The human side of these projects is intense and not all seniors wanted to participate. However, the seniors that have elected to work on these projects are unstoppable, and their self-motivation is infectious and invigorating. The two projects under way this year are the modification of the navigation system and a self-feeder for children without arm movement.

The Department of Physical Therapy is also working within this collaboration now. PT graduate students are working with some of same children through the Teacher Support Program, as well as other groups of people with physical handicaps. The University has recently created the Center for Adaptive Devices, which will "bring together faculty and students from the fields of engineering, technology, physical therapy, health sciences, gerontology and interior design to examine lifestyle issues facing impaired and aging populations, and then create solutions to help improve the quality of life for those populations"[7].

Conclusions

Senior projects are an excellent vehicle to solidify and integrate the knowledge, skills, and abilities inherent in an ECET program. These projects provide an excellent picture of the senior for potential employers and for visiting accreditation teams. Many of the program outcomes specified by TAC of ABET can be demonstrated through well executed senior projects.

While the above reasons are sufficient to justify senior projects, having projects that serve the community adds immense value to the seniors and is critical to the University. Western Carolina University is committed to service that extends the benefits of its scholarship to society. The collaboration demonstrated in this wheelchair navigation system is one example of this commitment.

References

1. ABET, Criteria for Accrediting Engineering Technology Programs, Internet Website, http://www.abet.org/images/Criteria/T001%2004-05%20TAC%20Criteria%201-19-04.pdf, page 19, (date accessed January 4, 2005).
2. M.H. Ahmadian, "Enhancing Students' Problem-Solving Techniques through a Special Project Course", in *Proceedings American Society for Engineering Education Annual Conference*, 2003.
3. W. Walter and M. Smith, "Handicapped Design Projects in a New Engineering Honors Course", in *Proceedings American Society for Engineering Education Annual Conference*, 2003.
4. M.C. Kreppel and M. Rabiee, "University/ Community Partnership through Senior Design Projects", in *Proceedings American Society for Engineering Education Annual Conference*, 2003.
5. P. Brackin and J.D. Gibson, "Service-Learning in Capstone Design Projects: Emphasizing Reflection", in *Proceedings American Society for Engineering Education Annual Conference*, 2004.
6. Teacher Support Program, Internet Website, http://www.ceap.wcu.edu/tsp/, (date accessed January 4, 2005).
7. Center for Adaptive Devices, Internet Website, http://www.wcu.edu/pubinfo/news/hightechinitiatives05.htm, (date accessed January 4, 2005).

Biographies

KENNETH BURBANK is an Associate Professor and Director of Electrical and Computer Engineering Technology at Western Carolina University. Dr. Burbank is active with IEEE, SME, and TAC of ABET, and strives to bring practical engineering activities into the classroom. His current projects are housed in the Center for Adaptive Devices**.**

JOHN HOLCOMB is a graduate of Western Carolina University with a BS in Electronics Engineering Technology. He is the current Elementary FOCUS Program Manager for Meridian Behavioral Health Services in Cherokee County, NC. Mr. Holcomb is an active member of IEEE and hopes to further continue his education in the near future.

KARENA COOPER-DUFFY is an Associate Professor and Director of the Special Education program at Western Carolina University. Dr. Cooper-Duffy specializes in preparing teachers to provide best practices for students with severe and profound disabilities.

KENNETH PROHN is the Project Coordinator of the Western Carolina University Teacher Support Program. Mr. Prohn has 25 years of classroom experience as a special educator and now offers an array of direct support services to all educators who serve students with disabilities.