AC 2007-3104: SENIOR DESIGN PROJECTS IN ASSISTIVE TECHNOLOGY: OPPORTUNITIES FOR TECHNOLOGY TRANSFER

Karen May-Newman, San Diego State University

Peter Newman, San Diego State University

Urban Miyares, Interwork Institute - Disabled Businessperson's Association

Senior Design Projects in Assistive Technology: Opportunities for Technology Transfer

Abstract

A unique partnership was established three years ago between an engineering senior projects program and a group of sailors with disabilities known as Challenged America (CA). Renewable funding was secured for three years from the National Science Foundation for engineering students to design various adaptations for the CA fleet of racing sailboats. These modifications allow the physically challenged individuals to not only safely and independently participate in sailing, but also to compete effectively against able-bodied teams. The designs are initially selected to fill a need for the sailors, but have proven to be useful to a broader range of individuals. One example is a knot-tying device that was developed to assist sailors on the boat, but has wider applicability as a teaching tool. Assistive technology has historically involved the development of custom-designed devices for specific individuals, however an organized design effort such as that provided by the engineering senior projects enables the design of devices that serve a larger population, and provide opportunities for technology transfer. Students learn from their involvement in the disclosure and patenting process which is relatively straightforward for these designs. While eventual commercialization may not yield a substantial profit, the product focus of the development effort benefits both the students and the disabled community.

Introduction

A longstanding interdisciplinary collaboration between the Colleges of Engineering and Education at San Diego State University led to a unique partnership established three years ago with a group of sailors with disabilities known as Challenged America. These individuals make various adaptations to their fleet of racing sailboats to compete effectively against able-bodied teams. Renewable funding was secured for three years from the National Science Foundation, through a program entitled "Engineering Senior Design Projects for Persons with Disabilities." The broad goal of this partnership is to develop technology solutions to allow physically challenged individuals to safely and independently participate in various aquatic recreational activities.

Proper design of the human interface is vital to the projects – the students must learn the limitations and capabilities of their clients and tailor their devices' functionality to match. User comfort and safety are important considerations, since many of the devices will be used during multi-day offshore races. The marine environment also poses some severe design constraints, and students must consider factors including saltwater corrosion, temperature extremes, dynamic loading forces due to motions of the boat, as well as electric power and weight limitations inherent to a racing boat.

Methods

A capstone design experience is considered paramount for undergraduate engineering students, as it requires students to work together to integrate the principles, concepts and techniques from earlier courses to solve an open-ended design problem[1]. A survey of 360 engineering programs by Todd and coworkers found that most engineering programs have these capstone courses, which range from 1-2 semesters and generally take place during the senior year[2]. Students must work in teams of 3-6 in the majority (83%) of programs, and work on the completion of a project solicited from faculty, industry, a sponsored design competition, or a student's own idea. The teams are advised by a faculty member, with whom they have weekly meetings, which carries a significant time requirement. The number of projects offered each semester varies, and does not always match the numbers of students especially in large engineering programs. Most projects can be completed on a modest budget, providing there is access to a machine shop and other needed fabrication facilities[3]. While the cost is not excessive, properly supporting these projects requires a significant continuous funding source, which is rarely available. Students are graded not only on their technical design and completion of the project, but also on project organization, oral and written communication, and team dynamics.

Important for achieving an optimal experience is for the students to have a worthy project, sponsored by an active client, and mentored by an instructor who inspires students to take ownership of the project[1]. This requires a significant organizational framework. A steady supply of new projects, advising mentors and funding must be established to provide a consistent quality experience for the large number of students in most engineering programs. This paper describes a partnership that addresses all of these issues as well as providing a venue for innovative research and technology transfer.

The structure of the San Diego State University undergraduate mechanical and biomedical engineering programs require that students participate in teams on sponsored design projects with a substantial mechanical design component during their senior year. Thus, a number of projects on relevant topics are required to support the undergraduate program. The senior design project is a capstone two-semester course sequence, in which students form teams and bid on projects sponsored by industry, faculty research, or occasionally an idea conceived by the students themselves. Weekly class meetings cover topics regarding project management, scheduling, and professional ethics as well as featuring seminars by guest speakers. Students are required to have weekly meetings with their project advisor throughout the two semesters of the course. The final product must involve significant design and be a physical device, computer model, or a complete description of a manufacturing process for a mechanical or biomedical application. For many students, this capstone design experience provides the most relevant preparation for working in industry, and marks a segue from their academic training into their professional careers.

Students in the capstone engineering course were recruited to design AT for the Challenged America program. A rehabilitation technology graduate student with a background in engineering was recruited to assist in mentoring the student teams. Teams of 2-4 students met their customers in the environment of their design application – a 40' Tripp sailboat known as the B'Quest. The B'Quest is a racing sailboat with a standard crew of 6-11 sailors. The students interviewed their clients, and distilled their needs and preferences into a list of design

specifications, which were approved by both parties. Students designed, built and tested prototype devices or scale models to solve those problems. Several inventive solutions have been devised, and some of the designs have undergone multiple iterations by successive student design teams, advancing the technology development well beyond what would be possible for any single team. Students learn from their involvement in the disclosure and patenting process which is relatively straightforward for these designs.

Results

Thus far, 34 students have worked on 11 team-based design projects, producing designs, analyses and prototypes for innovative AT that may enable sailors with a broader range of physical abilities to compete on a level playing field. Initially the designs were formulated to fill a need for the CA sailors, but some have proven to be useful to a broader range of individuals, such as elderly individuals that have developed some movement or dexterity limitations with age. As such, the devices have much greater potential for use and acceptance. Furthermore, slight modifications often enable the devices to assist able-bodied individuals to perform a task more quickly or easily, increasing the customer usage further. Two of the designs with wider applicability have been approved for provisional patents at San Diego State University.

One of these is a knot-tying device that was developed to assist sailors on the boat with tying a bowline knot. The bowline knot is used to secure lines to sails and lash other objects to the boat, and is one of the most common knots needed on a sailboat. A schematic for tying this knot is shown in Figure 1. The device consists of a plate machined of ABS, which can accommodate risers attached by a single threaded screw and oriented with pins. The risers have clamps attached that can be positioned to allow rope slippage in one direction but fixing it along the other. Four clamps positioned as shown in Figure 2 are needed to tie the bowline knot. The device can also be used to tie a half-hitch knot, and other knot styles are being tested.

The device has been tested on two individuals with limited dexterity, and has both enabled an individual who could not independently tie a bowline knot do so, and increased the speed and ease of an individual that was capable of tying the bowline. Additional testing and assessment are in progress.

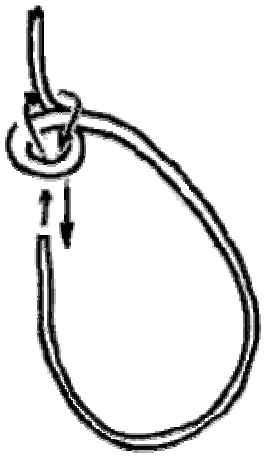

Figure 1. Diagram of how to tie a bowline knot.

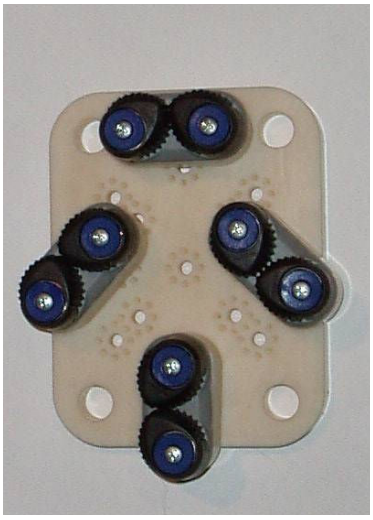

Figure 2. Prototype of knot-tying device.

Assessment

Two assessment tools were developed, one for the users and the other for the SDSU students. The users survey is completed by each individual using the device – this included several people for each device for the Challenged America projects. The survey asks the user to rate on a Likert scale how actively they were involved in the design process, whether their preferences and needs were considered in the design, if they would be comfortable using the device, and their experiences working with the student team. A survey for students was completed by each student participating in an AT design project to evaluate their interaction with the users, whether the device performed as expected, and the effectiveness of the experience in developing their engineering skills. The surveys are completed by the students when they complete their projects, and by the users when they test the designs.

Surveys of 9 students and 3 sailors found a high degree of satisfaction with the partnership on both sides. Responses were scored out of a possible maximum of 5, with 5 being the most positive. Students rated the overall capstone experience as positive (4.5/5) and strongly believed that the AT project was effective in developing their skills as engineers (4.4/5). The sailors were generally pleased with the devices and felt that their needs (3.9/5) and preferences (4.1/5) were considered. Overall, they rated the partnership with the students as positive (4.9/5).

Conclusions

Assistive technology has historically involved the development of custom-designed devices for specific individuals, however an organized design effort such as that provided by the engineering senior projects enables the design of devices that serve a larger population, and provide opportunities for technology transfer. While eventual commercialization may not yield a substantial profit, the product focus of the development effort benefits both the students and the disabled community.

Acknowledgements

The authors gratefully acknowledge the support of the National Science Foundation Grant BES-0314095. We would like to thank all of the students, particularly Ed Beail and Meral Demir, who participated in these projects, as well as Dr. Caren Sax for her assistance in designing the survey, A.J. de Ruyter for his efforts to help advise some of the student teams, and Michael Rondelli for his guidance through the technology transfer process.

Bibliography

1. Marin, J. A., Armstrong Jr., J. E., and Kays, J. L., "Elements of an optimal capstone design experience," Journal of Engineering Education, vol. 88, no. 1, pp. 19-22, 1999.
2. Todd, R. H., Magleby, S. P., Sorensen, C. D., Swan, B. R., and Anthony, D. K., "A survey of capstone engineering courses in North America," Journal of Engineering Education, vol. 84, no. 4, pp. 165-174, 1995.

3. Dutson, A. J., Todd, R. H., Magleby, S. P., and Sorensen, C. D., "A review of literature on teaching engineering design through project-oriented capstone courses," Journal of Engineering Education, vol. 86, no. 1, pp. 17-28, 1997.
4. Csikszentmihalyi, M., The psychology of optimal experience New York: Harper & Row, 1990.
5. Scherer, M. J., Living in the state of stuck, Third ed. Brookline Books, 2000.
6. Catalano, G. D., Wray, P., and Cornelio, S., "Compassion practicum: a capstone design experience at the United States Military Academy," Journal of Engineering Education, vol. 89, no. 10, pp. 471-474, 2006.
7. Conant, R. J. and Wells, M. K. Adaptive equipment design as an option for undergraduate engineering students. 107-108. 1990. Winter Annual Meeting of the ASME.