Senior Design Projects to Aid the Disabled

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Abstract

A new two-semester capstone senior design course sequence in the area of assistive technology has been developed and integrated within the established curriculum of the Department of Mechanical and Industrial Engineering (MIE) at the University of Massachusetts (UMass) Amherst. Entitled "*Senior Design Projects to Aid the Disabled*," the capstone sequence includes close collaborations with the Lemelson Assistive Technology Development Center (LATDC) at Hampshire College and Adaptive Design Services (ADS) under the Massachusetts Department of Mental Retardation (DMR). The new design course allows students to work directly with collaborators and disabled clients to solve specific assistive technology design problems. Through these projects, students enhance and reinforce concepts learned in their engineering education. At the conclusion of the sequence, each student will have conceived, modeled, analyzed, and built a functional prototype of a mechanical and/or electromechanical device that satisfies the specific need of an individual client. Early results of merging engineering education and an area of social significance have been very positive. Students have welcomed both the hands-on and personal contribution aspects of their projects. In many cases, projects have led to research extensions, additional community connections, and for many students, inspiration to continue with graduate studies. The objective of this paper is to report on the motivation, design, and results of the capstone course sequence in assistive technology. Specific projects, past and current, are also highlighted.

1. Introduction

In recent years, assistive technology has gained an increasing importance for people with visual, auditory, cognitive, or physical disabilities. Presently, over 35 million people in the United States have disabling conditions. This number is predicted to increase steadily over the next twenty years as the "baby boomer" generation ages[1]. In fact, the number of adults over 65 is the fastest growing segment of the population and will remain so for an extended period of time. It has been estimated that the average American spends approximately 12 years of their life as a person with disabilities. Since the passage of the *Americans with Disabilities Act*[2] in 1990, support in universities, private industry, and both state and federal governments has grown rapidly for using assistive technology to improve the lives of people with special needs. Private industry is increasingly designing consumer products for universal use by people of varying abilities. Federal agencies such as the National Institutes of Health (NIH)[3] and the National Science Foundation (NSF)[4] have increased budgets for assistive technology research in the past years. The Occupational Safety and Health Administration (OSHA)[5] is in the process of completing regulations governing workplace injury that will create a substantial market for assistive technologies on the job.

The capstone senior design course sequence to aid the disabled was developed to respond to the apparent need and growing demand for assistive technologies. In addition, the course sequence provides three important opportunities for engineering students and faculty, including:

1) Outreach to Disabled Community
   Students have direct access to practical real-world problems through close collaborations with nearby agencies and centers specializing in design for the disabled. Each student is tasked with finding solutions to satisfy specific needs of a disabled client. This link with the community through our collaborators helps build an active link between the students and disabled clients, promotes a personal bond, gives the students a sense of purpose and pride, and cultivates professionalism and social responsibility.

2) Interdisciplinary Education
   Assistive technology is an interdisciplinary field of great breadth. It encompasses electromechanical systems design, simulation, embedded computing, materials, human factors, and the understanding of assistive learning processes. Exposure of students to this broad field and contact with practicing industrial designers at an early stage in their career enhances their understanding of the importance of cross-discipline integration. This understanding is critical for today's engineers to face the challenges of the 21st century and provide better service to the society at large.

3) Integration of Research and Education
   The capstone course sequence enhances the efforts of the Department of Mechanical and Industrial Engineering (MIE) in its newly identified research thrust area in assistive technology and biomedical engineering. Taking full advantage of the advances in assistive technologies requires a systematic integration of the needs and performance capabilities of disabled persons, of mechanical, electrical and control technologies, and of design optimization. Frequently, addressing these challenges requires the integration of research and education. In our experience, senior design projects lead to the identification of research projects, research opportunities emerge from work with outside collaborators, and current faculty research informs senior design projects.

The sections that follow will provide a description of the course design, highlights of specific projects, past and current, and results and evaluation of the capstone course sequence in assistive technology. Conclusions and future plans are also provided.

2. Course Design

The senior design course is a two-semester (6 credit) capstone design sequence. All of the projects involve conceptual design, computer-based modeling and analysis, and the actual construction and testing of a working prototype that specifically satisfies the need of an individual client. An overview of collaborators and faculty that support this effort is provided first. The format and requirements of the course are then described.

2.1. Collaborators and Faculty Team

A diverse team supports students in the capstone course. Participants include the Lemelson Assistive Technology Development Center (LATDC) at Hampshire College, Adaptive Design Services (ADS) under the Massachusetts Department of Mental Retardation (DMR), and five UMass faculty with a wide range of expertise. This broad-based collaboration (see Figure 1) provides student designers with an intellectually stimulating environment and exposes them to the various aspects of assistive technology-related product design issues.

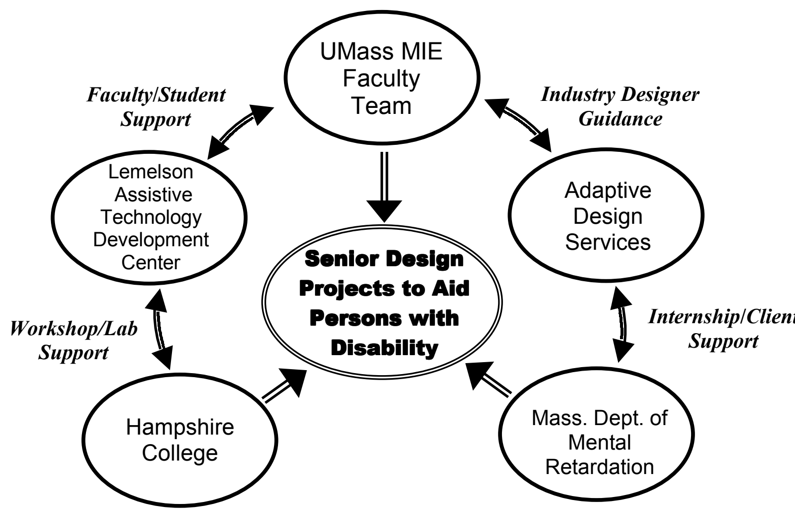


Figure 1. Foundation of the proposed senior design projects to aid persons with disabilities

Collaborators from LATDC and ADS provide project ideas, connections to disabled clients, expert advice and mentoring for students, and fabrication facilities. Collaborators participate in regular meetings and provide guest lectures on specific topics.

The five UMass faculty work closely as a team, coordinating the course activities and advising students. While each student has a chosen faculty advisor, the student is free to seek advice or expertise from any faculty or collaborator. The faculty have expertise in the following technical areas: 1) micro sensors and mechatronics (Prof. R. Gao), 2) materials and testing (Prof. J. Ritter), 3) human factors and ergonomics (Prof. D. Fisher), 4) design theory and methodology (Prof. S. Krishnamurty), and 5) design methodology and assistive/adaptive learning (Prof. J. Terpenny).

This diversity in faculty expertise, enhanced by the innovative and entrepreneurial environment at LATDC in Hampshire College (one of the five programs funded nationally by the Lemelson Foundation), and the long years of design experience of ADS designers in providing rehabilitative equipment for individuals served by the Department of Mental Retardation, allows students great flexibility in choosing their projects and a diverse team to support various aspects of their projects. Figure 2 shows graphically the expertise areas of the assistive technology faculty team at UMass.

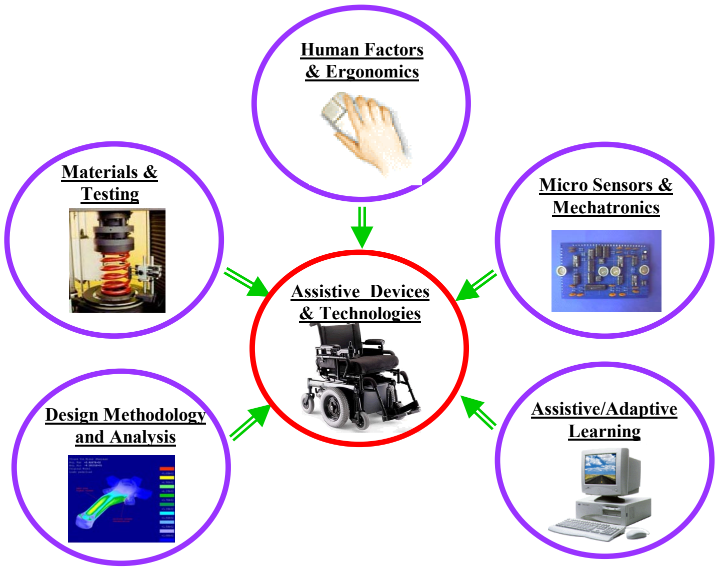


Figure 2. Areas of expertise of the five UMass faculty

2.2. Format and Requirements

Students may work in small groups or individually on a given project. The number and scope of assistive technology (AT) projects running in a given academic year can be quite varied depending upon the number of participants and their individual interests. It has been our experience that students are more committed and enthusiastic about their projects if they are free to investigate and perhaps identify project problems than if projects are only given to them on a list for selection. While a list of suggested problems is provided to students, it serves as input, not as an exclusive list of potential problems. The three phases of the design course are as follows:

1) Each student (or small group) meets with a disabled client either directly or through a coordinator from LATDC or ADS. The purpose of the meeting is to assess the needs of the disabled person and to identify specific requirements for an assistive technology design project. After the initial meeting, each student designer submits a written report that specifies the requirements that the design project must fulfill, and how the outcome of the design will improve the life of the disabled client.

2) Each student (or small group) then develops a conceptual design that satisfies the requirements. This phase takes the larger part of the first semester for the students. To justify the chosen concept, alternative design options must be presented and compared with the preferred design in terms of functionality, manufactureability, and cost. Rigorous models and analyses are included in this process. Three student presentations are required in the first semester. Problem identification and requirements, initial design alternative concepts and important considerations, and a final concept review where students present and justify their concepts to the group (other students, faculty team, and collaborators). Although left to the discretion of the student and faculty advisor, students generally meet weekly with their advisor. Students meet with collaborators and clients as needed. Most students take frequent advantage of the freely provided support from outside the university.

3) In the final stage of the course sequence, students are required to construct the design, build a working prototype, test it in the field with the client, and make any necessary modifications to achieve design optimization. Coordination of these tasks is the responsibility of the students and may include the acquisition of needed materials and components, learning new fabrication skills and how to use unfamiliar test equipment. Shop personnel, faculty, and collaborators support and may assist these tasks. Students have access both to the student workshop at Hampshire College and the MIE student shop at UMass. The student shop at Hampshire College has a wide variety of metal forming and finishing machines, fiberglass composite molding equipment, and welding facilities. The student shop at UMass has similar but limited equipment; however, students also have access to the complete machine tool facilities and technical support of the College of Engineering machine shop.

A seminar series intertwines with student presentations resulting in weekly group meetings. We find that weekly group meetings are essential to creating the team and community environment that is integral to the success of the design course sequence. Seminars may include off-campus researchers in disability studies, industrial designers, and assistive device manufacturers. The purpose of the seminars is to present state-of-the-art of assistive technology research and development. The seminars take advantage of existing collaborations with LATDC and ADS, and reaches out to other interested parties in the region and the State. Faculty from UMass and Hampshire College also participate in the seminar series providing course modules to address special technical topics that are not covered in the regular MIE curriculum. Table 1, shows the schedule for the fall semester of 2000.

Additional resources also help to support the senior design project experience. A web page, located at http://mielsvr2.ecs.umass.edu/at/, provides a valuable tool to participants, including schedules, requirements, supporting links, contact information and serves as a repository for project descriptions and presentations. Two graduate students, whose research is in the area of assistive technology, are available to senior students for questions, maintain the web resources, and are responsible for the implementation and maintenance of equipment and technology in our growing AT student design laboratory.

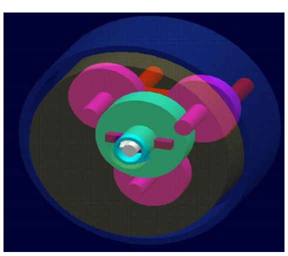
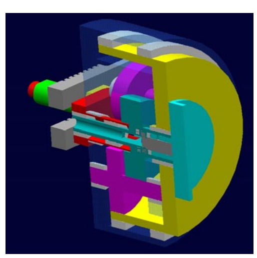
Table 1. Schedule for Fall 2000

Date	Activity
9/8	Organizational Meeting
9/15	LATDC Visit
9/22	ADS Visit
9/29	Student: Project & Advisor Selection
10/6	Faculty Presentation: Material Selection
10/13	Faculty Presentation: Project Manangement
10/20	Faculty Presentation: Mechatronics Student: Project Design Specifications
11/3	Faculty Presentation: Human Factors
11/10	Student: Conceptual Design Presentation
11/17	Faculty Presentation: Kinematics
12/1	Shop Tour and Lecture
12/11	Student: Final Concept Design Details and Analysis Report
12/15	Student: Final Concept Design Presentation

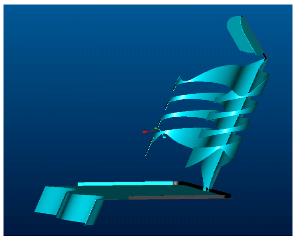
3. Highlights of Projects

This section provides brief highlights of several student projects from the assistive technology capstone course sequence. For each project, a brief problem statement, CAD model, and photograph, when available, are provided. Additional details for each project can be obtained from the course web site located at http://mielsvr2.ecs.umass.edu/at/.

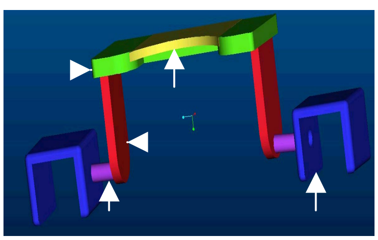
1) Impedance to wheelchair motion on inclines can cause considerable difficulty and come from a variety of sources, including soft soil, grass, carpet, hills, and ramps. A solution was needed to provide mechanical advantage on demand. The proposed solution envisioned: a variable transmission for a wheelchair - design of a mechanism that enables easy manual switching of the wheelchair transmission system to adapt to uphill or downhill ride situations.


2) Persons with a tendency towards having seizures who are confined to a wheelchair can be thrown from the chair during a seizure if not restrained. Alternatively, they can also be hurt by a restraining system during a violent seizure. A dynamic seating system was envisioned to detect and possibly prevent seizures. A new sensor technology that can be custom fit into a wheelchair to detect in real-time the inception of seizures and actuate a protection mechanism causing the chair to recline and prevent body injuries of a patient due to falling out of the chair was envisioned. Prevention of seizures through interruption by startle effect was also pursued. Although not completed in every regard, this project resulted in an initial prototype and continued research.

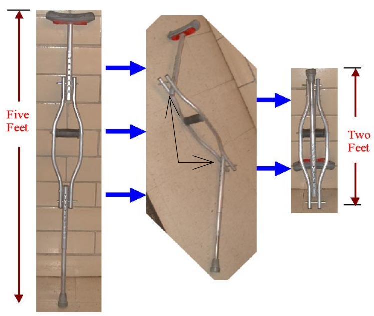


3) Trays for wheelchairs can provide a convenience to their users for regular activities such as eating, written work, computing, and a variety of other activities needing a flat horizontal surface. At the same time, if not properly designed, trays can be inhibiting, restrictive and inconvenient. A retractable tray for wheelchairs was envisioned that would provide an easily maintained, removable, unobtrusive, and universally adaptable tray for various wheelchair-based applications.

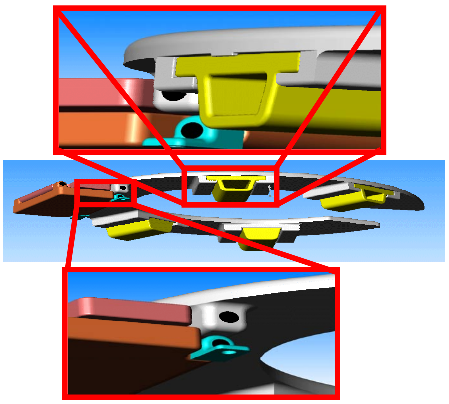


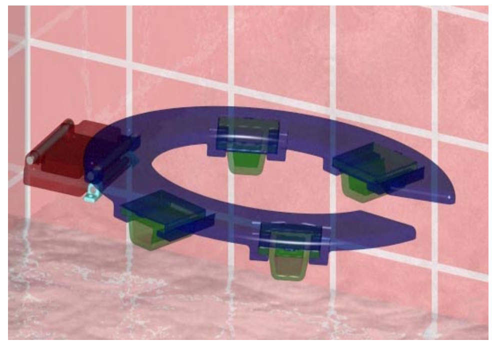
4) In every day usage, persons in wheelchairs are faced with many obstructions. Often times, damage is incurred to the chair, or worse, the user's feet and legs due to bumping into a door or wall. The solution: a retrofitable wheelchair bumper that is attachable to the wheelchair that helps prevent both foot/leg injuries of the user and chair structural damage due to direct chair-door collision. The bumper is versatile and attachable to most chairs. It is hinged and light weight making it additionally usable.

5) The main disadvantage of standard underarm, laminated wood or aluminum crutches is that they are awkward to put in an automobile or set aside in a classroom or lecture hall. The only full height, collapsible underarm crutch design available on the market today is telescopic in nature and retails for about $180. For comparison, the standard crutches retail for about $20 to $30. An aluminum crutch was designed that could be folded into thirds to allow the user to fit it into a gym bag. By constructing the folding crutch out of standard extruded aluminum tubing and using only "off-the-shelf" items, the increase in cost as compared to that of standard aluminum crutch is relatively small, while the value added is quite substantial. The value added is the compactness and easy storability of a folding crutch.



6) The existing Raised Toilet Seats (RTS) for the disabled function well, but can be quite costly, adjusting heights on the seat can be difficult, and most RTS are aesthetically displeasing. Through research done on the Internet, it was observed that existing RTS had several flaws in their design. By increasing the functionality of the existing RTS, decreasing the cost to the consumer, and making some aesthetic improvements to the design, it was determined that a RTS could be designed that could be beneficial to everyone, not just the disabled. Based on the engineering analysis and use of the Cambridge Engineering Selector (CES) software, a new design was developed.





4. Results and Evaluation

The two semester capstone senior design projects to aid the disabled began with the 1999-2000 academic year. Four students were enrolled, each taking on an individual project. All students worked hard and with the assistance of collaborators at LATDC and ADS, UMass faculty, and shop staff, successfully completed their project, including a working prototype. Ultimately, three of the four students went on after graduation to pursue graduate studies in areas related to biomedical engineering or assistive technology. Due to the public service nature of the projects, several opportunities for additional presentations and news interviews occurred making the students somewhat instant celebrities.[6,7,8]

To assess the success of the course, feedback was solicited at the end of the course from students, the five faculty at UMass, collaborators at LATDC in Hampshire College, and industrial designers at ADS. Overall, comments were very positive. Constructive comments included the need for more structure and more frequent meetings as a group. This suggestion was incorporated for the 2000-2001 academic year, reflected previously in Table 1.

The 2000-2001 academic year has also seen a remarkable growth in the number of participating students. Twelve projects, some individual and some small groups, are now in progress. In addition, while LATDC and ADS continue to be our primary partners, collaborations are expanding this year with additional parties in the community and local agencies seeking participation. Further, building upon our initial year of experience, we were successful in obtaining funding from the Biomedical Engineering Program for Senior Design Projects for the Disabled at NSF and an internal public service grant at UMass to expand our efforts.

5. Conclusions and Future Plans

In conclusion, we believe that the senior design capstone course sequence in assistive technology has been well worth the resources and effort that were required. Students are expanding and reinforcing their engineering education well beyond the traditional capstone experience and faculty are collaborating with one another and outside centers/agencies in new and diverse ways. The community is benefiting from the projects and avenues for new research are expanding.

Our future plans include efforts to expand the participation of students and collaborators in the capstone course. The design course sequence will be opened to any UMass senior student in engineering or computer science as well as to students associated with LATDC at Hampshire College. We also anticipate expanding the seminar series. Continuous improvement through regular feedback and workshops will also be used to inform and improve the design course sequence.

Acknowledgments

The authors gratefully acknowledge the funding received from the National Science Foundation (NSF, BES-0001347) and the Public Service Grant received from the University of Massachusetts Amherst to support this work. Very special thanks go to our collaborators from LATDC (Colin Twitchell and Lauren Way) and ADS (Richard Goldman and Carl Johnson) who have provided projects, time, materials, funds, expert advice, student mentoring, and on-going connections to the disabled community making this work so successful and fulfilling.

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Biographies

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