Rehabilitation Robotics and Assistive Technology Experiences for Engineering Technology Students

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Abstract

The Engineering Technology Department at the College of Engineering at Cal Poly Pomona (CPP) offers degrees in two areas: Electronics/Computer Engineering, and Mechanical/Manufacturing Engineering technology. Engineering technology education is enhanced through the students' exposure to inter-disciplinary concepts that help them to generate better solutions to problems while facilitating communication with different specialists in a team. As one of the leading colleges of engineering, our mission is to link theory and practice via our learning-by-doing philosophy.
To be in alignment with this mission, students in both areas of engineering technology can take a technical elective course in robotics and applications during their senior year. In this course, they learn the basic principles of the science of manipulation along with basic control of robotic manipulators. In the laboratory portion of the course, they work in interdisciplinary teams and build a robotic manipulator with the interface to teleoperate it by using a haptic device. They apply the system for specific tasks of activities of daily living (such as lifting an object and moving it to another place etc..). In addition, those students who have an interest in biomedical applications can take independent study credits to work on extensive research/literature review of state-of-the-art technology and develop prototypes of assistive technology and rehabilitation aid devices.

Background

The engineering technology department at Cal Poly Pomona has a committed mission of educating engineers by engaging them in active learning and experimenting. Learning-by-doing is a method of education that aims at bringing students' knowledge to hands-on practice and experiments as quickly and as purposefully as possible. Over the past two decades, the method has been formally adopted by several colleges and engineering departments at ABET credited undergraduate universities. The Integrated Teaching and Learning Lab at the College of Engineering and Applied Science in the University of Colorado at Boulder is probably a pioneer in formally practicing the method and publishing scientific educational reports on the results[1-4]. Other examples of the established programs over the past two decades are the Information Engineering Technology (IET) program at the Northern New Mexico College, the University of Texas at Austin Project Centered Education (PROCEED), and reflection-in-action software engineering courses at the College of Computing, Georgia Institute of Technology[4]. The PROCEED program of UT Austin for instance was initially started in the department of

Mechanical Engineering for undergraduate courses and has been going on for about 15 years. The program has a mission of turning students' education hands-on as quickly and as practically as possible. To reach this goal all lectures are closely accompanied by computer-aided modeling and laboratory experiment. According to the statistics provided by UT Austin's website the program currently covers 12 classes and involves many faculty members and students[3].

In all the instances of academic models for learning-by-doing that we examined, the method is either practiced as an in-class type of exercise, in the form of laboratory and computer modeling assignments, or as long-term student research projects. Depending on what form is implemented, there are always requirements and upgrades that has to be carried out at different levels for successful results, including:

1) Modifying classroom content and presentations to provoke students' participation
2) Restructuring homework assignments and course evaluation system
4) Modernizing classrooms and laboratory equipment for facilitating experimental observation and education for students, and providing access to computer-aided design and engineering programming tools.
3) Defining modern collaborative research projects for students
5) Establishing strong partnership with industry
6) Designing interdisciplinary courses and research projects that require students to self-educate on broader scales of topics and study areas.

At the department of Engineering Technology at CPP, these elements are emphasized and practiced regularly at teaching and in-class levels. As the department is leaning towards establishing a strong research program in addition to existing teaching infrastructure, efforts have been dedicated to develop more active undergraduate research projects and elevate learning-by-doing capability of the department at the research level. To that aim, it is crucial to focus on multidisciplinary areas of research that also have the potential of partnership with strong industrial sides. The field of biomedical robotics is in a way unique in satisfying both of these two criteria. Robotics and biomedical engineering are both extremely multidisciplinary and vast areas with practical essence for different levels of hands-on experiments. Students involved in rehabilitation robotics research have a chance to acquire a background in multiple areas such as engineering of mechanical moving and dynamic parts, control systems, electrical sensory motor systems, neurological systems and some levels of medical science. Additionally, due to large amount of global research activity and public interest in biomedical robotics, there are numerous opportunities for industrial partnership. In fact, this field is so suited for undergraduate research education that the Engineering Department at CPP has exclusively established a Robotics Education through Active Learning (REAL) program. According to [5], "REAL is designed to inspire students and prepare teachers. REAL is the culmination of an extensive, six -year collaboration among engineering faculty, undergraduates, and K-12 teachers in robotics-based education to engage and inspire learners".

Rehabilitation robotics is the engineering of applying robotics to retrieve muscle and nervous system functionality in people who has disabilities due to neurological disorders. These robotic devices can act both as supportive tools to facilitate regular actions of the disabled body parts, or help retreat motions in clinical or real-life experiments. Originally it dates back to 1990s when major break-through accomplishments occurred in robotic and biomedical technology[6] and it has been a very active clinical and commercial research field since then. Rehab robots can be primarily categorized based on the region of body that they serve to improve motor movement. The majority of rehab robots are designed to assist patients or disabled people recover movements in arm, spines and legs. Therefore, the most common types of rehabilitation robotic devices are: aiding limb or hand movement exoskeletons, enhanced rehabilitative (e.g. antigravity) treadmills, robotic arms, finger rehabilitative devices and motorized neck braces.

Rehab robots can be either passive or active and can also be classified based on the type of user interaction and degrees of freedom in controlling patients movements (e.g. the number of contact points)[7]. Conventional rehabilitative robots which were mostly adopted from industrial robots were mostly robotic manipulanda with one point of contact between the robot and patients body, whereas more modern robotic orthosis consist of continuous or multiple point contacts with the body[7].

At present, the market of rehabilitation robotics engineering is extremely active and extends to commercial products and clinical experiments. A few notable examples of commercial devices are:

Bionic Legs:

1) Tibion Bionic leg of Tibion Corp. which is designed mostly for stroke patients whose leg functionality are affected by the condition, and provides the opportunity to stand safely, walk and climb[8],

2) Ekso Bionic Leg of Ekso Bionics which is the producer of exoskeletons for survivors of stroke or spinal cord injury or other forms of extremely weakness that facilities walking. Ekso has strong research ties with UC Berkeley and has been supported by the US Department of Defense.

3) AlterG which is a producer of both bionic leg and anti-gravity treadmills

4) Rewalk which is a producer of bionic walking assistance systems for standing upright, walk and climb stairs.

Treadmills:

1) Lokomat treadmill by Hocoma which according to the company's website is a "driven gait orthosis that automates locomotion therapy on a treadmill and improves the efficiency of treadmill training". Hocoma, a Zurich based company also produces other products such as Erigo (combined leg robotic assistant and back stabilizer system), and Arimo (robotic arm and hand rehabilitative system)

2) AlterG anti-gravity treadmill

Robotic Arms and Finger Braces:

1) Myomo robotic arm brace (MyoPro) which is designed to assist patients in need of arm rehabilitation or robotic assistance due to stroke, neurological damages such as MS, Traumatic Brain Injury, Amyotrophic Lateral Sclerosis, Spinal Cord Injury or Brachial Plexus Injury.

2) Amadeo of Tyromotion which is a finger and hand rehabilitation system.

3) Bi-Manu Track of Reha Stim (a Germany-based company) which is one of the very early clinical devices for reanimating arm movements by initiating both passive and active mode moves and allowing the brain to mirror the healthy side moves for rehabilitation of the unhealthy side.

4) HapticMaster of Moog Inc. a company involved in design and manufacturing of motion control technology for military (space, submarine, etc.), energy, industry and medical customers, and is also the producer of Wristalyzer (a wrist perturbator device) and Dental Trainer (simulator) products.

There are also several notable example of clinical and academic rehab robotic systems. These systems are often more advanced in terms of the underlying pattern-based training and software than the stand-alone commercial products. A few of the most notable systems are:

1) MIT Manus (a.k.a InMotion) which is an arm rehab manipulanda robotic system developed at MIT and is based on an interactive smart training software for best treating patients with neurological disorders[9].

2) Mirror Image Movement Enabler (MIME) developed at Stanford University with 2 degrees of freedom which is also an arm rehab system[10].

3) Therapy-Wilmington Robotic Exoskeleton (T-WREX) developed at UCI which is a passive arm exoskeleton orthosis[11].

4) Reharob of the Budapest University of Technology.

5) The ARMin system developed at ETH University which is an arm therapy robotic system[12].

Sample Student Projects

1. Mechanical Prototype for Bimanual Rehabilitation for Stroke Patients

An interdisciplinary team of mechanical and electronics and computer engineering technology students investigated various robotic devices currently employed in upper limb rehabilitation for post-stroke patients. After extensive literature review, they focused on the work done by researchers at the University of South Florida[13] on bimanual rehabilitation devices and developed a basic prototype. The idea of a bimanual rehabilitation device is to allow an individual to self-rehabilitate by guiding his paretic arm with his healthy arm using an external physical coupling.

With regards to actual rehabilitation exercises, the device must be able to allow three main types of bi-manual rehabilitation exercises; joint space symmetry, point mirror symmetry and visual symmetry. All three can be accomplished through a combination of joints and linkages available through the device. The device consists of one revolute joint and three prismatic joints.

The prismatic joints allow for motion in the x and y planes, which facilitates visual symmetry and joint space symmetry exercises. The revolute joint is rendered immobile for these motions through the use of a pin. Two of the prismatic joints are used to connect the stroke affected arm with the healthy arm through a pulley system. This system allows each arm to either mirror or oppose the actions of the other arm, depending on how the lines routed through the pulleys. For example, the arms can be made to close or increase distance with one another such as a clapping motion, or to move together in the same direction where one arm mirrors the motion of the other. The third prismatic joint allows the entire assembly to travel in the y axis, allowing for movements either away from or toward the patient. For the exercise requiring point mirror symmetry the revolute joint is freed by removal of the pin and the y axis degree of freedom is removed by use of a friction lock. The two prismatic joints allowing for travel in the x axis are linked to allow for a mirrored motion where the arms will either come together or travel apart.

In constructing the device, simple materials such as plywood and aluminum were used to keep the overall costs efficient. The rails used for movement in the y axis are industry standard extruded Aluminum t-slots available from a number of suppliers. Arms for the device are sized to be standard Aluminum square stock to minimize machining time. The base for the device is ½ inch plywood for ease of transport and assembly. Figure 1 shows the SolidWork model designed by the students, and Figure 2 shows a picture of the mechanical prototype.

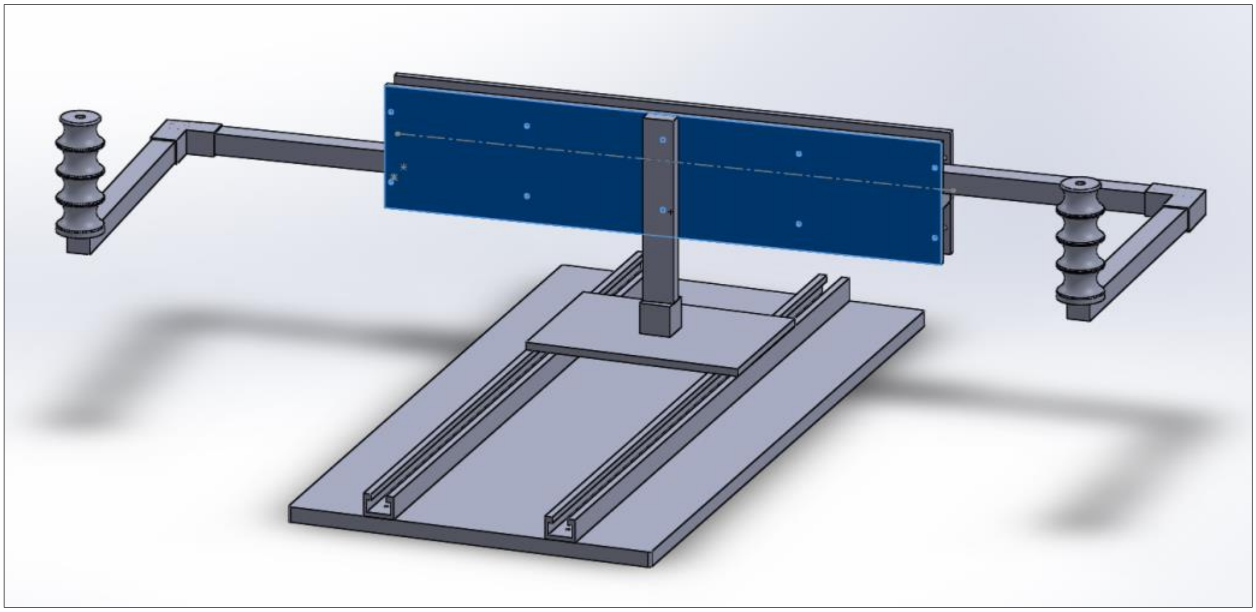

Figure 1. SoliWorks Model for the Bimanual Rehabilitation Robotic Device

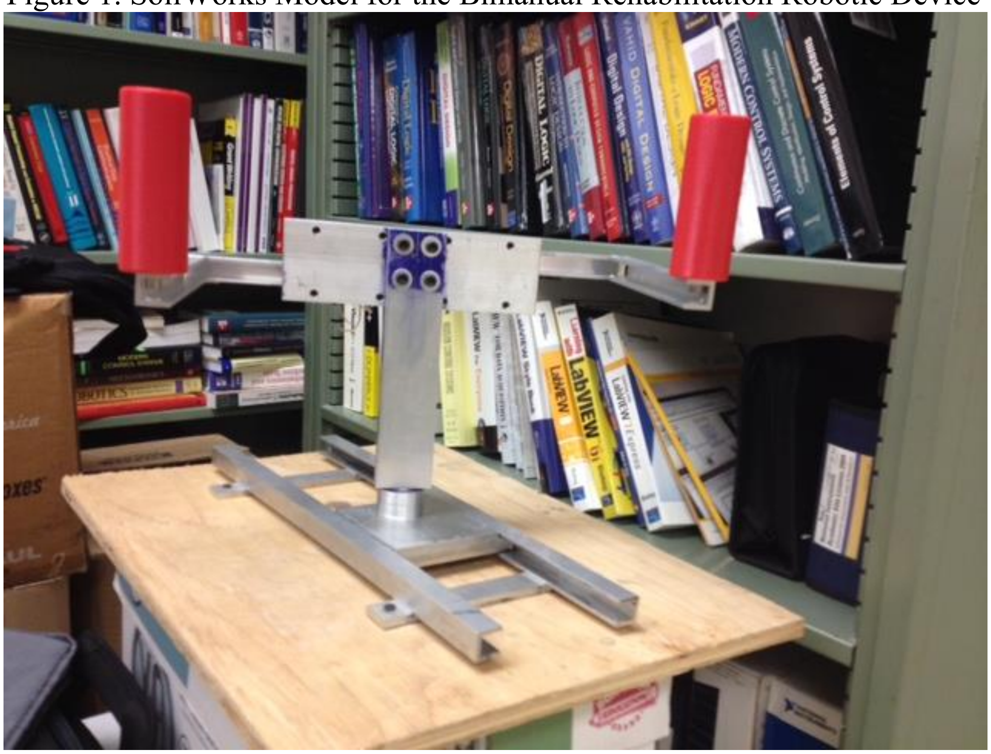

Figure 2. Mechanical Prototype for the Bimanual Rehabilitation Robotic Device.

2. Motorized Neck Brace for Rehabilitation Exercises

Another team of students developed a motorized neck brace for people in need of neck rehabilitation exercises, or people who have lost motion and control of their neck. The goal was to develop a brace that not only assists the user with neck rehabilitation but also improves peripheral safety. The brace use is considered a dynamic assistive step before it is fully removed, and has even long term applications for patients with neck paralysis.

The prototype developed provides support through a limited range of motions which allow for quicker neck rehabilitation. It is not intended to solely limit motion like a conventional neck brace does by applying resistive loads, as that could be very uncomfortable for the user. For patients in need of neck rehabilitation, the motorized neck brace allows for an adjustable range of motion which will allow for faster healing times. Increased peripherals reduce eye fatigue and increases safety by adding more peripheral viewing and less wear on the user. In order to adjust the appropriate electric motor weight specifications, a standard weight of an adult head and length of the spinal column were taken into account. Figure 3 shows the working prototype.

Figure 3. Motorized Neck Brace Prototype

3. Derailleur Gear Wheelchair Proposal

Another team of students conducted literature search and presented a proposal that could give future students the opportunity to develop the working prototype. This proposal presents the implementation of a derailleur gear system capable of transitioning an individual between various speeds and easing overall mobility of a wheelchair. The finished product will consist of modifying an existing wheelchair to be compatible with a gear system that the user will be capable of operating. This added feature will be directly mounted to the frame of the chair and attached by two hand operated levers for ease of access, providing stability and extra control to the user at an affordable cost compared to electric powered alternatives. The device will be installed so that the user can move with less energy expended and easily propel themselves up steep inclines while experiencing less muscle strain. Figure 4 shows the proposed idea

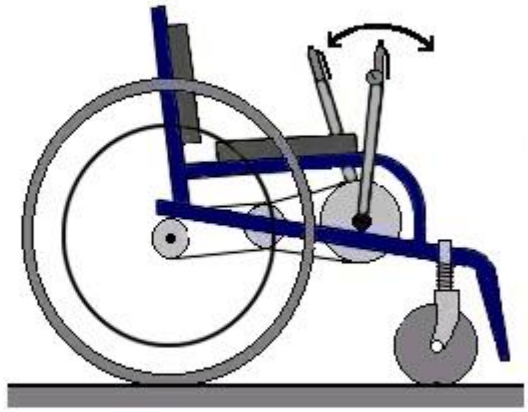

Figure 4. Proposed Idea for a Derailleur Wheelchair

4. Telerobotic Haptic System

Engineering technology students take a technical elective course in robotics during their senior year. In this class, they design and build a telerobotic (master-slave) system to execute a simple activity of daily living. They use a Novint Falcon haptic device on the master side and build a manipulator for the slave side of the system. They design and build the interface in LabVIEW and design and build the electronics to control the slave manipulator. Some students have adapted off-the-shelf robotic kits for the slave manipulator. Figure 5 shows two of the systems.

Figure 5. Telerobotic Haptic Systems

Conclusion

Engineering technology students from both areas have shown great appreciation of the opportunity given to work in interdisciplinary teams applying their knowledge to biomedical related problems. The field of rehabilitative robotics is an excellent opportunity for students to perform hands-on research on various engineering topics. Therefore the Engineering Technology department at Cal Poly Pomona has a particularly dedicated program in this area. These projects have provided engineering technology students an experience in line with the learn-by-doing philosophy at Cal Poly Pomona. In this paper, we reported several student projects in designing robotic systems for patients with disabilities due to stroke or other neurological disorders. These projects include a Mechanical Prototype for Bimanual Rehabilitation for Stroke Patients, a prototype for Motorized Neck Brace for Rehabilitation Exercises, a design proposal for a Derailleur Gear Wheelchair Proposal, and a LabVIEW interface for designing Telerobotic Haptic System.

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