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BRIGE: Translating Robotic Technology for Inclusive Fitness: An Innovative Robotic Rowing Exoskeleton (RRE) Development Project

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Organization: University of Maine

Submitted By:

Deshpande, Ashish - Principal Investigator

Title:

BRIGE: Translating Robotic Technology for Inclusive Fitness: An Innovative Robotic Rowing Exoskeleton (RRE) Development Project

Project Participants

Senior Personnel

Name: Deshpande, Ashish

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: DePoy, Elizabeth

Worked for more than 160 Hours: No

Contribution to Project:

Dr. Deshpande collaborates closely with a researcher from the Center for Community Inclusion and Disability Studies at the University of Maine, Dr. Elizabeth DePoy. Dr. DePoy contributes with her personal and academic experiences in disability and community inclusion. DePoy's collaboration provides the expertise necessary for usability and safety research, and provides greater access and communication with the broader disabled community. In addition to her substantive research expertise, DePoy provides a role model for women and disabled students.

Post-doc

Graduate Student

Name: Rao, Prashant

Worked for more than 160 Hours: Yes

Contribution to Project:

Prashant conducted the literature survey on the biomechanics of indoor rowing, and also on the existing exoskeleton robots. He worked with another undergraduate student, Brian McLaughlin, to develop a prototype design for the shoulder-arm exoskeleton. He also conducted studies to choose the actuators and mechanism parts for the exoskeleton.

Undergraduate Student

Name: McLaughlin, Brian

Worked for more than 160 Hours: Yes

Contribution to Project:

Brian worked with Prashant to develop a prototype design in 'SolidWorks'. He then machined parts for the mechanisms and assembled the first version of it. He also assisted in the literature survey on exoskeleton robots, and in choosing the actuators and controller for the robot.

Name: Gatewood, Eileen

Worked for more than 160 Hours: Yes

Contribution to Project:

Eileen assisted in the literature survey on ergometer rowing. She also studied the methods for collecting data with human subject involving a motion capture set up and electromyography (EMG) sensors.

Name: Gurschick, Kalee

Worked for more than 160 Hours: Yes

Contribution to Project:

Kalee assisted in the study of biomechanics of rowing by studying the data collected on human subjects with a motion capture system.

Name: Collett, John

Worked for more than 160 Hours: Yes

Contribution to Project:

John wrote programs in Matlab to store, categorize, and analyze biomechanical and kinematical data on rowing. He also assisted in controller design for the robot prototype.

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities:

? We have analyzed the biomechanics of rowing with healthy subjects. This is achieved through a detail literature survey and also through studies conducted in the lab.
? We have translated the movement analysis findings into the design of an upper extremity robotic rowing exoskeleton (RRE) which will allow persons with motor and strength limitations to participate in rowing.
? Based on the models developed for rowing biomechanics we have come up with a design for the rowing exoskeleton.
? We have developed mechanisms for the first prototype of the RRE with the focus on backdrivability of the mechanism which is critical for effective human robot interactions.
? Some of the aspects of mathematical modeling and mechanical design have been incorporated by the PI in an undergraduate class titled 'Kinematics of Mechanisms.

Findings:

Rowing Biomechanics
Rowing is a complex motion involving multiple joints and numerous muscles whose movements and actuations must be coordinated precisely to achieve efficient and effective rowing actions. A number of researchers have studied the biomechanics of rowing. We have carried out a detail literature survey of these works and also conducted studies in the lab, to develop detailed mathematical models of rowing biomechanics. Our models predict the movement and force generation patterns during rowing. The models show that the elbow and knee joint go through much larger range of movements than the shoulder and hip joints. Our models also predict the joint torque necessary at the shoulder and elbow joints which give the necessary values for the robot actuator design.
Prototype Design
Based on the literature survey of biomechanics of rowing and studies in the lab we have designed the first prototype for the RRE. One of the key goals is to make the robot adaptable to the human limbs in terms of segment lengths, range of motion, and the number of degrees of freedom. The design of an exoskeleton requires various trade-offs, which limit the achievable performance of the device. The design choices might limit or affect human motion abilities. We have designed the first prototype of the RRE with the robot segments that are of variable lengths in order to make the robot adaptable to different body sizes.
The prototype has four degrees of freedom, two for each hand. The shoulder and elbow joints will be driven by actuators and the plane of workspace of the robot is adjustable. The exoskeleton will be attached to hands from above, therefore patients will have enough space for rowing and the patient sits in the chair of rowing machine which is beneath the robot.
Improving Backdrivability of the Actuators
In rehabilitation robotics, the actuators must be able to deliver high torques at low velocity. To achieve this many of the rehabilitation robots are driven by a combination of motors and gearboxes. Geared actuators lead non-backdrivable mechanisms due to friction in the gearbox which

could lead to uncomfortable and even unsafe human-robot interactions because these rehabilitation robots are attached directly to the human. For the RRE design it is necessary that the motions delivered to the limb are gentle and avoid unexpectedly large forces. To achieve this the robot must be designed to be backdrivable by the patient.
The back-driving torque, 𝜏𝑏, can be defined as the amount of torque the human must apply to the robotic joint in order to perform a user-driven movement. Perfect backdrivability is achieved if 𝜏𝑏=0. While admittance controllers perform well with non-backdrivable actuators (𝜏𝑏≫0), impedance controllers require actuators with good backdrivability (𝜏𝑏≈0). In the RRE design we chose the actuators, gear system and controllers that will lead to highly backdrivable exoskeleton. On top of these design choices we are developing a control scheme to improve backdrivability. While it is common practice to compensate for friction, by using velocity measurements, and the fact that the direction of the desired motion is often known in rehabilitation can be utilized to achieve better backdrivability. Our controller takes advantage of the desired direction of motion to compensate for the friction in the system.

Training and Development:

Through this project found undergraduate students, including two women, got the opportunity to be involved with engineering research for the first time in their careers. The undergraduate and graduate student was guided by the PI, and the graduate student had the opportunity to assist the PI in mentoring some of the undergraduate students.

The students were exposed to research in disability studies through Dr. DePoy's mentoring and came to appreciate problems and potential problems associated with the daily activities of persons with disabilitities. The research experience and training prepared the undergraduate students to seek employment in emerging fields of robotics, biomechanics, and controls.

Outreach Activities:

The project is hosted in the ReNeu Robotics Lab directed by the PI. The Lab actively participates in the outreach program run by the College of Engineering at the University of Maine.
The Lab hosted more than ten demonstrations for the middle school and high school students from all parts of Maine. For many of the students it was their first exposure to research in robotics and biomechanics, and it expanded their vision of possibilities of engineering careers.

The Lab also hosted three half-day long hands-on workshops for middle school and high school girls from various parts of the State of Maine. The workshops involved teaching the students how the human muscles and tendons actuate the joints, and how to develop simple models of human kinematics and biomechanics.

Journal Publications

Books or Other One-time Publications

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Conference Proceedings

Special Requirements

Special reporting requirements: None
Change in Objectives or Scope: None
Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Organizational Partners
Any Journal
Any Book
Any Web/Internet Site
Any Product
Contributions: To Any within Discipline
Contributions: To Any Other Disciplines
Contributions: To Any Human Resource Development
Contributions: To Any Resources for Research and Education
Contributions: To Any Beyond Science and Engineering
Any Conference