Prosthetics and Rehabilitation Robotics

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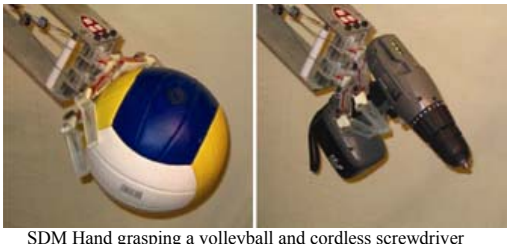
As a participant in the Roadmapping Workshop for Medical and Healthcare Robotics, I will be able to contribute my expertise related to the application of the principles of robotics to prosthetics and rehabilitation devices. At the workshop, I will discuss my work related to upper- and lower-limb prosthetics and active braces for the lower-limbs.

My work in graduate school included the development of a novel robot hand that is both compliant and highly underactuated. The hand uses only a single actuator for the eight joints yet is able to passively adapt to large variations in object geometry - unparalleled performance in unstructured environments with natural applications in upper-limb prosthetic devices. In my postdoctoral work I am developing robotic othoses to assist those with neurodegenerative disorders resulting in weakness of the leg muscles. As a junior faculty member (I am currently negotiating offers and will likely start in January 2009), I will be working in parallel in rehabilitation robotics and robot manipulation.

Upper-limb Prosthetics

Over 10,000 major amputations of the upper extremities occur every year in the US alone. However, while technology has improved drastically, very few advances in prosthetic devices have been adopted by the amputee community in the last century. During their every day lives, most patients still choose hooks or other simple mechanisms as terminal devices for functionality, switching to a less functional, more cosmetic terminal device for social activities.

During the workshop, I will discuss how I plan to address this dichotomy by developing an extension of my grasping research to work towards the development of a hand prosthesis that is both multi-functional and realistic. Size and weight constraints as well as limitations inherent with both myoelectric and body-powered methods of control and actuation limit the number of degrees of actuation that can reasonably be incorporated into a prosthesis. The strategy I have taken with hand design fits well with this problem – careful choice of compliance, smart design of joint coupling, and an emphasis on durability. I have taken steps in this direction in a paper I presented at the 2007 IEEE International Conference on Rehabilitation Robotics in which I analyze the performance of my SDM robot hand in the context of a prosthetic terminal device - work which was awarded the Best Student Paper Award.

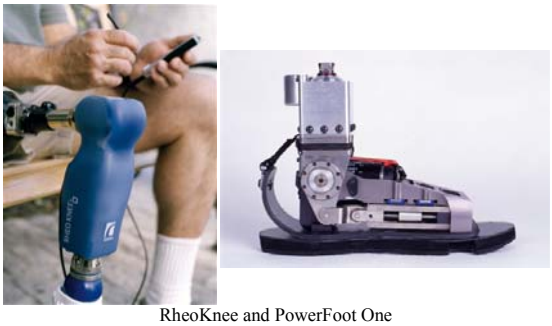


SDM Hand grasping a volleyball and cordless screwdriver

I will also discuss how my approach contrasts that of the DARPA “Revolutionizing Prosthetics” program, one of the few recent concerted research efforts in this area. This program, I believe, has focused on approaches that are too mechanically complex to be commercially viable or acceptable by the amputee community.

Lower-limb Prosthetics

During the meeting, I will also serve as a representative for Professor Hugh Herr, for whom I am currently a postdoctoral associate. Dr. Herr is perhaps the world's foremost expert on the development of robotic prosthetic devices for the lower limbs. Unfortunately, due to scheduling conflicts, he will not be able to attend. However, I will meet with him extensively before the workshop and bring to the table his perspectives on the issues at hand.

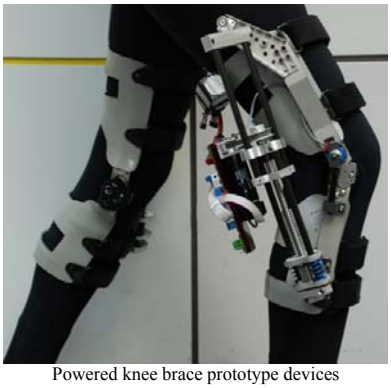


RheoKnee and PowerFoot One

Two of the most significant contributions of Dr. Herr's laboratory to the field of active prosthetics devices are shown in the figure. The first of these is the RheoKnee, a variable-damper knee prosthesis (commercialized by Össur Inc.) that is one of the most sought-after knee prosthetic devices. More recently, Dr. Herr's lab has developed the world's first powered ankle-foot prosthesis that significantly improves amputee walking economy versus commercially-available devices. This prosthesis is currently being commercialized through his company, iWalk Inc.

Active Orthoses for the Lower-limbs

The main thrust of my current research is focused on developing robotic rehabilitation aids for the injured and disabled, particularly for the lower limbs. Nearly 7 million people in the US suffer some form of leg weakness and would benefit from the use of an orthosis. However, with few exceptions, options for orthotic devices (braces) for this population are limited to passive technologies that cannot provide the augmentation necessary to replicate the function of an unaffected limb. Accordingly, there is great potential for the development of electromechanical devices to drastically increase the quality of life of this population.



Powered knee brace prototype devices

I will discuss my plan to develop mechanically simple powered orthotic devices that harness the passive dynamics of locomotion to reduce energetic requirements. I am currently working on two projects related to this goal. The first is a knee-ankle-foot orthosis designed to provide power to the knee and ankle in order to both assist the wearer during ambulation in their everyday lives and provide a variable level of assistance for therapy purposes. The second is a powered knee brace for running that captures the energy typically absorbed by the knee at heel strike and released during the successive positive power phase, reducing the metabolic energy required by the wearer.

I will also bring to the table my understanding of the state-of-the-art in this area. I have published what I believe is the only review article related to powered exoskeletons and active orthoses for the lower limbs (A.M. Dollar and H. Herr, "Lower Extremity Exoskeletons and Active Orthoses: Challenges and State of the Art," *IEEE Transactions on Robotics*, vol. 24(1), February 2008.). During the course of my research for this article, I not only developed a strong grasp for what has been done in the field, but have also identified important research areas that have yet to be addressed.