NSF/CCC/CRA Roadmapping Workshop for Medical and Healthcare Robotics

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2. Current Research
   a. DOD Grant – Design a prosthetic ankle, SPARKy, Spring Ankle with Regenerative Kinetics, TATRC organization
   b. NIH Contract – RUPERT, Robotic Upper Extremity Repetitive Training
   c. NIH Grant – Robotic Spring Ankle Assistance for Stroke Survivors

Broad Research Goals

The central theme of my research is the integration of robotics and humans. This interaction holds promise to facilitate critical advancements in a variety of emerging domains including medical rehabilitation, physical therapy, and assistance of elderly and weak individuals. Past robots have been very successful at repetitive, position-control tasks, but interaction between robotic devices and users has not been emphasized until recently. My research program addresses this need in several promising areas such as the development of wearable robotic systems used in the fields of medical rehabilitation and assistance, and the understanding of human navigation. My vision is to develop future generations of robotic systems that interact with, aid, and enrich humans in medical and health care tasks.

The principal challenge in order for robots to be seamlessly integrated into the human environment is to be able to achieve human-like characteristics for intelligence, motion, sensory perception, and communication. Currently, robots do not store information and move in a safe compliant manner that interacts with the intentions of a user. They have limited intelligence to learn and adapt and have difficulty communicating in a way that people find natural.

I focus on the integration of robots to assist in rehabilitation and medical therapies, such as the design of compliant spring actuators that can safely assist human movement, and the development of intelligent controllers based on human perception. (I am not focusing on other critical areas such as intelligence and communication.) I am designing wearable robotic systems for stroke therapy, ankle prosthetic systems, and am collaborating with psychologists to understand human perception and navigation. I will outline 3 areas that I believe should be included into a Roadmap for Medical and Healthcare Robotics.

1. Stroke

Over 750,000 people each year in the United States suffer from stroke which can lead to serious long-term disability. In order to assist stroke survivors, new robotic research has focused on designing exoskeletons. Studies have recently shown that repetitive task therapy using robots allow neural re-training of the brain. These new robots allow for therapy at home and in the clinic. They are also able to efficiently gather data.

A key component to developing wearable robotic systems is the development of new actuators that can provide compliant force control. The problem with current designs are their low power and energy density and complicated control methodology. New actuators are a key challenge towards realizing biomimetic wearable devices. Generally most systems use powerful active motors instead of adaptable, compliant devices.

Once robust, take home devices are designed and researched, a key challenge is user acceptance and diligence at performing the therapy. Keeping the subjects motivated will always be a challenge. Important research areas: design of exoskeletons, design of intelligent controllers that can adapt their assistance level, development of motivational robots, and development of robots that can easily communicate with users and therapists.

2. Prosthetic systems

Because today's body armor is very good, many soldiers are living, but are returning from Iraq with loss of limbs. In the civilian population, diabetes is growing rapidly causing many individuals to have limbs amputated as well.

Today's foot-ankle prosthetic devices are still largely passive and untunable. They typically use rubber like springs or leaf springs made from carbon composite materials. They do not contain powered elements that assist in locomotion. Amputees must rely on the limited spring-back passive devices provide and modify their gait to help propel themselves forward. Amputees cannot drastically change their locomotion conditions due to the unchangeable parameters of their prostheses. Carrying heavy loads or transitioning from walking to running using a single device remains a challenge. Amputees frequently change from one device to another to meet these conditions. Even though current powered systems represent a vast improvement from the rigid and damper based systems, they are inadequate for majority of high level amputees.

Very sophisticated wearable robotics systems are needed for the amputee population. Again similar challenges arise such as the need for powerful but lightweight and efficient actuators. Determination of the user's intention is the greatest challenge. Researchers are using EMG signals, neural interfaces, and Bions.

3. Studying Human Navigation – Collaboration with Psychologists

"Robotics can also be used to augment and stimulate basic science to understand human health. The ability to create a robotic system that mimics biology is one way to test and possibly demonstrate that we know how the human body and brain function."

Biomimetic robotic systems can aid researchers in biology and psychology to understand human perception. We have found that mobile robots using human, perception-based algorithms can instantiate the perception based research of psychologists. Interdisciplinary teams can test perception algorithms on robots to see if they are viable and roboticists can point to different perception algorithms that are more feasible when implementing them on hardware. In this one example, medical systems could be developed for the visually impaired.

4. My expertise to the panel is in systems design, development, and control. I am developing exoskeletons for stroke survivors and transtibial amputees. I have served on SBIR panels on medical assistance devices. I look forward to contributing to the panel in any way and am very interested in the final results.

Sincerely,
Thomas G. Sugar, PhD, PE