Space Robotics Technologies for Medicine and Healthcare

Proposers: Curtis Collins, Matt Heverly, Hari Das Nayar, Adrian Stoica and Ashitey Trebbi-Ollenu
Point of Contact: Hari Das Nayar
MS 82-105, JPL, Caltech, 4800 Oak Grove Drive, Pasadena, CA 91109.
Phone: 818 393-2505, E-mail: hari@jpl.nasa.gov

Background:

The Jet Propulsion Laboratory (JPL) has an extensive and highly-regarded robotics research and development program primarily focused on space applications. JPL has particular expertise and recognized leadership in research on mechanisms and mobility systems design, modeling and simulation, sensing, estimation and control, machine vision, artificial intelligence, and machine learning. Many of these technologies can and have been applied to solve problems in medicine and healthcare.

One example is the Robot Assisted MicroSurgery (RAMS) system[1] that was built on JPL's force-reflecting telemanipulation technology. Developed more than 10 years ago, RAMS was a pioneering demonstration of tele-robotic micro-surgery that combined force-feedback with micron-level positioning. There are potentially many other applications where JPL's robotics technology, honed on highly challenging, extremely remote and hostile space environments, can be applied to medicine and healthcare.

We have identified four topical areas as particularly aligned with JPL's robotics expertise. They are: robot surgery, rehabilitation systems, robotic assistive devices and robotic personalized medicine. The following chart (Table 1) matches areas of JPL's robotics expertise to these applications.

	Mechanisms	Mobility Systems	Modeling	Simulation	Sensing	Control	Machine Vision	3-D Visualization	Artificial Intelligence	Machine Learning
Robot Surgery	x		x	x	x	x	x	x		
Rehabilitation Systems	x	x	x	x	x	x	x	x	x	x
Robotic Assistive Systems	x	x	x	x	x	x	x	x	x	x
Robotic Personalized Medicine			x	x	x	x		x	x	x

Table 1. JPL robotics technologies applicable to medicine and healthcare

We describe below how our robotics technologies can extend, benefit and enhance the state-of-the-art in the respective applications for medicine and healthcare.

Surgical Robotics:

Although this field has matured and commercial systems are available, there are many shortcomings yet to be addressed. Some innovations that would greatly improve surgeons' capabilities include:

- Intuitive interfaces that enable surgeons to use minimally invasive techniques with the apparent look and feel of open surgery. Sensing, modeling, machine vision, 3-D visualization and virtual environments can aid in the development these new generation of surgeon interfaces.
- Macro-micro manipulation systems that enable precise positioning of surgical instruments over a large workspace and enable simple set-up procedures for a variety of procedures combined with surgical planning software can address problems of lengthy preparation times needed with current systems. The RAMS system (see Fig. 1), for example, is an ideal candidate micro-robotic system to be mounted on a macro-positioning robot.

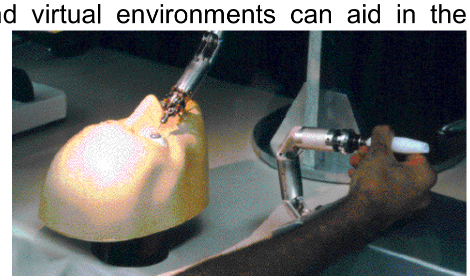

Figure 1. RAMS system

- Utilization of alternative materials, mechanisms and sensing in the manufacture of robotic systems to allow real-time imaging, for example, MRI or CT scanning during surgical procedures.
- Remotely operated robot surgery systems for use in inaccessible or poorly serviced environments can bring cutting-edge surgical techniques to a wider population and potentially reduce cost. Signal-delay compensation and telepresence technology can be used for practical implementations. Similar systems can also help in training surgeons.

Rehabilitation Systems:

While robotic systems have been used in physical rehabilitation research for directing motion and providing controlled compliance, significant work remains to bring this technology into clinical and home settings. Further improvements are needed in the areas of hardware, sensor, and system design. These include:

- Mechanical system designs specifically matched to the workspace, force, and compliance requirements of human physical rehabilitation. These will likely be dual-limb systems designed with soft and smooth features that promote safety and enhance tactile characteristics for patient interaction.
- Advanced force and contact sensing systems that can be used to resolve and control forces applied to the patient and by the patient. These whole-arm sensors can monitor all physical interactions with the system.
- System level designs that can be adapted to multiple patients, multiple protocols, and multiple stages in the rehabilitation process. This will require the programming or teaching modes, as well as monitoring modes.

Robotic Assistive Devices:

Assistive mobility and manipulation systems can benefit from technology developed at JPL for planetary surface systems. Substantial contributions toward improved assistive device technology can be made in the following areas:

- Utilization of rough-terrain mobility, autonomous navigation, hazard detection and obstacle avoidance while maintaining safe, stable behavior for assistive mobility systems. Technologies developed for the Mars rover missions are just as applicable for terrestrial applications.
- New concepts for powered walkers, and related systems can be drawn from unique mobility systems developed at JPL. An example is the ATHLETE (see Figure 2) rover that combines wheels and legs for mobility.

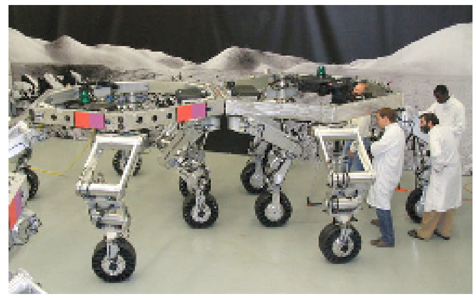

Figure 2. ATHLETE rover

- Manipulation systems utilizing advanced materials, alternative actuators (for example, piezo-electric motors), sensing and control for attachment to mobile robots, wheelchairs or integrated into specialized systems for assistance in particular household situations for example, in handicap-accessible bathroom designs, patient transfer in hospitals or physical therapy are areas where JPL's expertise can be applied.
- Intelligent user-interfaces that augment and compensate for limitations in user capabilities by building on JPL's mission sequencing and planning tools, machine vision and artificial intelligence.

Personalized Medicine:

Personalized therapies optimized for patients depending on their individual needs based on specific diagnostic, genetic and behavioral inputs are emerging as feasible and effective means of providing healthcare. In personalized medicine, diagnostic, other information such as the individual medical history, genetics, continuous monitoring of body parameters, etc. would be used. Research advancements are needed in the following areas that relate to both modeling and simulation tools and physical robots:

- Rapid/optimal design of customized/individual-specific prosthetic devices.
- Design of individual-specific organs (organ growth on scaffolds built to fit specific individuals' biometrics, tissue compatibility).
- Pills for monitoring inside the body (lab-on-a-chip microsystems with transmitters etc), or for releasing drugs-(decision making can be made inside).
- Manipulation, machine vision, search and optimization mechanisms for automated sequencing.
- Intelligent implants, brain interfaces that record/learn individual's behavior and could be transported to personalized robots.
- Networked personalized health-oriented environments.

Conclusion:

Although we are currently focused on space applications, we have strong interests in applying our expertise to medical and healthcare robotics. We have continued to maintain strong relationships with potential collaborators at other research, academic and clinical institutions through past collaborations and mutual interest. We are also fortunate to be located in an area where there are many opportunities to work with world-class medical institutions to provide clinical grounding for any research we conduct. The exchange of ideas between space robotics and medicine and healthcare can lead to revolutionary new approaches that benefit humanity.

References:

1. H. Das, S. Charles, T. Ohm, C. Boswell, G. Rodriguez, R. Steele, E. Paljug "A Telerobotics Workstation for Microsurgery", in Proceedings of the Medicine Meets Virtual Reality:5 Conference, January 1997, San Diego, CA.