PROPOSAL FOR THE NSF/CCC/CRA MEDICAL AND HEALTHCARE ROBOTICS WORKSHOP

Charles L. Ortiz, Jr. Thomas Low Pablo Garcia
William Jarrold Benoit Morisset Bart Peintner Enrique Ruspini
SRI International
ortiz@ai.sri.com
650-859-4461

BACKGROUND

The interdisciplinary Center for Research on Independent Aging (CRIA) at SRI was created to pursue the mission of: 1) characterizing and predicting deficits and conditions that impede independent aging; 2) preventing or treating conditions that impede independent aging; and 3) for deficits that cannot be prevented or treated, providing adaptive assistance to maintain independence to support aging in place, safely at home. CRIA is a diverse collection of SRI researchers (for example, robotics, AI, micro-sensors, cognitive science, health sciences) working on aging-related problems and technologies.

SRI research in **medical robotics** has focused on developing enabling technologies and applications for robots in the operating room and in the field[1]. We are currently developing TraumaPod, a first generation autonomous robotic system for both the treatment of wounded from the battlefield as well as their automated stabilization during transport to locations for definitive treatment. TraumaPod integrates medical imaging modalities, such as limited angle computed tomosynthesis (CT) and ultrasound imaging, with automated diagnosis and robotic procedure modules. Other areas of research in telerobotic medicine at SRI include: ultra-lightweight portable manipulator systems, rugged systems for extreme environments, robotic systems inherently safe for operation in the proximity of humans, dexterous endoscopic manipulation for single port or NOTES procedures, autonomous conduct of image guided medical interventions, remote image-based diagnostic procedures (CT, limited angle CT, Ultrasound, Multispectral Imaging, MRI), hybrid robotic and telerobotics systems and optimized man-machine interfaces, robotic acquisition of serial ultrasound data to track and monitor the advancement of a disease or the effectiveness of a treatment regimen, and robot-integrated tools for energy-based dissection and joining of tissue.

Figure: The da Vinci System in use and an artist's rendition of the TraumaPod system under development.

Researchers at SRI, collaborating with other institutions, have been involved in efforts to develop **household robots for the elderly**, focusing on activity recognition and the generation of reminders in a way that is sensitive to a person's schedule, the social context, and the desire to avoid having the older adult become dependent on the reminders. The same technology was adapted and tested with Traumatic Brain Injury patients with memory impairment. This work included demonstrations and user tests in healthcare facilities and in the homes of patients, providing a valuable perspective on how those with impairments view assistive technology and on the challenges of integrating technology into healthcare regimens of those with cognitive impairment.

PROPOSED RESEARCH TOPICS FOR THE ROADMAP

Improving the safety of medical robotic software and hardware. Software for medical devices is increasingly complicated as their functionality becomes more sophisticated. For medical robots in particular, failures in the system can result in life

[1] In the 1980s, SRI developed the first telepresence surgery technology as part of a battlefield-based trauma surgery system. In 1995, SRI formed Intuitive Surgical and in 1999 Intuitive launched the da Vinci Surgical System. In 2000, da Vinci was cleared by the FDA for general laparoscopic surgery; since 2000 the FDA has cleared it for thoracoscopic surgery, cardiac procedures performed with adjunctive incisions, and urologic and gynecologic procedures.

threatening situations. A study by the FDA determined that a significant number of recalls are attributable to software failures. Most current work in software certification is based on standards that govern the process by which the software is constructed. We propose taking an explicit, evidence-based approach that leans heavily on *formal software verification technology* for modeling the electronic and physical components, the human user, the software control as well as the interaction between these components. This approach will ultimately reduce the time and risk involved in bringing medical robots to the market.
There are an increasing number of robotic applications requiring high payloads and accuracy, which need to operate safely near humans. The only available manipulators capable of high loads and accuracy are industrial robots, which are hazardous when operating in close proximity to humans due to their high mechanical impedance. There is a need for technologies which would *make robotic manipulators inherently safe around people*. We propose investigating a number of different approaches, from novel actuators to compliant skins and control systems that can stop a manipulator before a full impact. These technologies should widen the acceptance of manipulators for applications in which humans work together with robots.

Intelligent Assistive Sensors. The objective of our research in this area is the development of intelligent sensors to enhance the cognitive and sensory functions of the elderly. Our initial focus is on artificial olfaction (AO) devices, such as food-poisoning detection devices, which could be incorporated on robotic platforms to provide sensing throughout a household, providing enhanced olfactory functions to the aged and permitting them to remain independent by mitigating errors made because of sensory losses. The National Institute of Allergy and Infectious Diseases (NIAID) (FoodNet Network Statistics) and the Centers for Disease Control and Prevention (CDC) estimate that 76 million people suffer from foodborne illnesses each year in the USA, accounting for more than 325,000 hospitalizations and more than 5,000 deaths. Adjustment of these figures to estimate the incidence of foodborne diseases on those over 65 indicates that approximately 123,000 hospitalizations are caused, in the USA, by foodborne infectious diseases including botulism, campylobacteriosis, E. coli, hepatitis A, norovirus, salmonellosis, and shigellosis to elderly patients. Our approach combines our past work in the development of AO sensor arrays able to detect E.Coli and our subsequent work on ChemArray, a device having much wider biological detection capabilities. Development of sensor arrays incorporating a large number of sensors (over 93,000 in ChemArray), however, results in massive vectors that must be exhaustively analyzed to determine (1) the signatures associated with agents of interest, (2) the effectiveness of the sensor array (selectivity, sensitivity), and (3) the contribution of individual sensors to the performance of the array. Our approach makes use of adaptive cognitive sensing techniques, where the sensors not only gather data and feed back instructions but, additionally, uses the sensory data to reconfigure the sensors themselves as required to perform intelligently designed follow-on sensory functions.

Assistive robots inhabiting 3D environments. The majority of commercial robots today assume an essentially 2D environment: robots are deployed in indoor structured environments and are capable of mapping such spaces and then navigating through them. To be truly assistive to the elderly, however, robots will need to be able to both navigate within and manipulate objects in *complex 3D environments*. For example, a robot that could augment the physical capabilities of a person with limited mobility would need to be able to do such things as navigate through a cluttered kitchen, open a cabinet or a refrigerator, look for objects, and avoid obstacles both on the floor and in the path of effectors (such as a robot arm for grasping). A prerequisite for such behavior is the ability to generate and reason over 3D models of the environment. Indoor lighting conditions and the lack of texture within such environments (walls, floors, etc) introduce additional challenges by restricting the usability of approaches based on stereo vision alone. Under DARPA funding, SRI is developing algorithms and software that can support robots that can navigate through and over such complex environments using sensors such as LIDAR and flash LADAR. Extensions to these sorts of approaches that can additionally support the use of many degree-of-freedom robotic arms of the kind that SRI has been developing under the TraumaPod project described above, represent a pressing need that must be addressed before robots can co-habit complex spaces and participate in or perform the sort of everyday household tasks described above.

Augmented modes of interaction for robots interacting with the autistic. Robots can assist in the development of social skills in the autistic. We are exploring means of eye direction detection: people with autism lack theory of mind ability and some researchers believe that detecting direction of eye gaze is a very important pathway that leads to development of theory of mind. Detecting eyes is a problem that has been solved in recent years; there are commercial systems that can also track eye gaze. One can apply such technology to human-robot interaction so that a robot could interact with an autistic child and also facilitate the child's learning of that skill. More generally, eye direction detection is a fundamental component of any social robot. People communicate intent with eye direction. In stroke victims with impaired language ability, tracking eye gaze will render robots more useful as they will be better able to determine what the patient wants. Automatic speech processing is another technology that could improve interactions between a robotic tutor and an autistic person. Emotion or prosody is essential to social functioning; people with autism have difficulty with communication at that level. If a robot as social tutor is to be useful it will need to be able to recognize appropriate and inappropriate affect. SRI has developed the Algemy toolkit which has already been useful in recognizing affect. The goal here is to continue developing this technology especially within the constraints that a robot imposes.