CCC Roadmapping Proposal

Healthcare and Medical Robotics Workshop

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Meka Robotics is a spin-off from the MIT Computer Science and Artificial Intelligence Lab. We have a strong background in adaptive robot manipulation as demonstrated in our work with the robot Domo [1,2,3,4]. In particular, we are focused on development of safe and compliant manipulators and on human-robot collaboration during manipulation tasks. We are also involved with Hstar Technologies where we work with the Army Telemedicine Advanced Technology Research Center in the development of assistive robots for healthcare [5].

We see a strong need for physically assistive robots in healthcare. Robots that can provide basic physical assistance to the elderly will allow them to stay at home longer, reduce the strain on an already overloaded healthcare system, and off-load the physically demanding work currently performed by healthcare providers. We consider the following research areas to be particularly relevant for discussion in the workshop:

Mobility Assistance

Mobility assistance is a fundamental need of elderly people at home, at assisted living centers, and at the hospital. Getting in an out of a chair, out of bed, and walking to the toilet can all require the assistance of a healthcare worker. This requires fundamental research and development in to:

1. **Intuitive human interfaces**. An elderly user of a robot assistance device will not receive extensive training. Consequently, these devices must support human-robot-interaction protocols that are intuitive and leverage existing user experience. One type of interface could be based on social cues such as pointing and physical contact as these are nearly universally understood by people.
2. **Sensing and control of contact forces**. Active assistive devices will need to sense physical contact with potentially frail patients as well as safely control these interactions forces. This requires novel force control strategies, algorithms for dense tactile sensing, and development of new force and tactile sensor technologies.

We are currently involved in a project to create a robotic nurse assistant (RoNA) that provides physical assistance to nurses on a hospital ward. It will help a nurse transfer patients between beds and get out of bed. We anticipate that RoNA systems would increase a nurse's work satisfaction, decrease lifting-related injuries, and extend the years of effective service nurses could render in hospitals. These effects would reduce hospitals costs and ameliorate the problem posed by the shortage of nursing staff.

Human Safe Manipulators for Healthcare

Commercial robot manipulators are currently designed for speed, precision, and repetition in factory automation tasks. Accidental human contact with these manipulators can be quite dangerous, so workers are fenced off from the robots. Advances in healthcare robotics will require robot manipulator technology that can accommodate safe human contact, and fine sensing and control of contact forces. Today's healthcare robots typically do not have manipulators, effectively limiting their usefulness to applications such as drug delivery and tele-presence. Human-safe manipulators for healthcare will enable a wide range of applications such as physical rehabilitation, positioning of medical devices (such as ultrasound), and tele-presence augmented with the ability to perform basic manual tasks such as picking up a dropped object.

This requires fundamental research and development in to:

1. **Theoretical analysis of manipulator safety**. We will need a framework for designing safe manipulators that includes top-to-bottom analysis of the mechanical, electrical, and software systems.
2. **Compliant actuators.** It has been shown that mechanical compliance in actuators can provide intrinsic safety. However, this compliance can also limit the manipulator performance. Novel actuators capable of dynamically varying their mechanical stiffness can allow for both safety and high-bandwidth control. Likewise, these actuators must capable of precise sensing of small, subtle interaction forces while being able to lift heavy loads.
3. **Task space controllers.** Healthcare manipulators will require robust controllers that can provide singularity-free control of possibly redundant manipulators given only high-level task-space directives. This will allow for a variety of healthcare applications to be developed independent of the underlying hardware. For example, a generic reach-and grasp controller will allow doctors to remotely inspect a patient or for a patient in a wheelchair to pick up a dropped object.

References

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[2] Edsinger, A. and Kemp, C., Human-Robot Interaction for Cooperative Manipulation: Handing Objects to One Another, *Proceedings of the IEEE International Workshop on Robot and Human Interactive Communication (ROMAN)*, Jeju, Korea, August 2007.

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[4] Charles C. Kemp, Aaron Edsinger, and Eduardo Torres-Jara. Challenges for Robot Manipulation in Human Environments. IEEE Robotics & Automation Magazine. (Volume 14, Issue 1), pg 20-29, March 2007.

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