Submission for the NSF/CCC/CRA Roadmapping for Robotics Workshop:
A Research Roadmap for Medical and Healthcare Robotics

Holly Yanco
UMass Lowell
Computer Science Department
One University Avenue, Olsen Hall
Lowell, MA 01854
phone: (978) 934-3642
fax: (978) 934-3551
holly@cs.uml.edu

Research Area 1: Design of More Effective Human-Robot Interaction

To date, human-robot interaction for commercially available assistive robot systems has fallen short. For example, the Manus ARM, a wheelchair mounted robot arm, is shipped with a choice of one of three hierarchical menus that go up to three layers deep. Such a menu structure requires that the person using the system have very high levels of cognitive function; for the Manus ARM, a twelve hour training session is required for a user to start using the arm. However, many people who could benefit from the use of a wheelchair mounted robot arm do not have the necessary cognitive ability to operate the arm.

In our research, we have been investigating how a user can directly select a desired object through the use of a touch screen or laser pointer. Once the selection is made, the arm moves autonomously to retrieve the object. This interaction method is much more effective for people who have cognitive disabilities in addition to physical disabilities. It also mimics how people without disabilities target an object and then reach for it without considering every small movement. An assistive device should not require its user to do more work than is needed without the device. People don't think about moving their joints in space; we should not require the user of a robot system to think this way.

We must design human-robot interaction that can be used by all, not just a small percentage of the people who would benefit from its use. The principles of universal design can be applied, but we must also develop guidelines for the design of HRI for target populations as well as procedures for evaluation that will be adopted by all.

Research Area 2: Identification of Human Cues

Humans use numerous cues in their environment in order to achieve goals and function efficiently in both known and unknown spaces. We look for signs to find shops, we look for doors to enter buildings, and we find someone's office number by looking for a directory on the wall. These cues affect our internal representation of the world by providing semantic labels for locations or objects and also dynamically change the way we interact with other people by providing common anchors for queries or responses. By developing robot vision systems that can interpret these cues, we can create robot systems with more robust navigation capabilities, allowing for novel environments to be mapped using simultaneous and localization mapping (SLAM) algorithms with the detected human cues used as semantic labels on the map.

However, the development of vision algorithms alone is not enough to improve robot systems. The location and interpretation of text on signs is a difficult problem. In an academic office environment, for example, door signs are often surrounded by other postings such as conference posters, office hours, and comic strips. When room numbers are located, commonly used statistical text analysis techniques do not constrain the problem – one number is just as likely to follow another, unlike in English text, where some letters are more likely to follow others. Additionally, in some buildings letters are often used in combination with numbers for identifying rooms. In human spaces, interaction with people is one approach to obtaining information when visual data is ambiguous or difficult to parse.

One of the limitations of current semi- and fully autonomous robot systems that function in cooperation with or in spaces designed for humans is the rigidity of the human-robot interface. For example, the interface for a robotic wheelchair will focus on its kinematics such as the desired direction and speed, or perhaps let the user select a goal destination on a previously created map that has been hand-labeled with room names. Giving a robot the ability to detect and use human cues as part of the interface creates two opportunities in HRI design: the robot can integrate those cues into the interface and the robot can make use of the user as a potential information source to disambiguate text.

The ability to interpret human cues in the environment will allow for the development of many different robot systems for healthcare. For example, a robot wheelchair that can read door signs will be able to more efficiently navigate to given locations, particularly in buildings being visited for the first time. Robot arms with the capability to recognize elevator buttons and read the numbers, text or symbols on them will give additional accessibility to people in wheelchairs who also have limited limb mobility.

Research Area 3: Explainability and Trust

There is a need to for a robot system to be able to summarize its state and the actions that brought it to this state after periods of autonomy (or even semi-autonomy); most often, robots can move autonomously until they hit a difficult situation. Expecting a person to intervene without understanding how the robot came to the current point will result in failure. We must develop effective methods for state summarization – and state includes more than just the current sensor readings of the robot.

Additionally, developing the ability for a robot system to explain its actions will be key to building trust in the users of a system. Consider a person using a robot wheelchair: if the system makes unexplained and sudden turns when the person does not perceive any immediate danger, the person is likely to lose trust in the system. However, if the system can explain why it is about to take an action, trust can be built. Research is also needed to determine the level and amount of explanation that should be given.

Not a Research Area, but of Importance for Commercialization

In order for robot systems for healthcare to be commercialized, we will need to address how the FDA will approve these systems. At present, most companies will not consider commercializing a robot wheelchair system due to the FDA approval process as well as liability issues. We must address these problems in order to achieve the promise of our research.