2012 IEEE/RSJ International Conference on
Intelligent Robots and Systems
October 7-12, 2012. Vilamoura, Algarve, Portugal

Robots for Humanity: User-Centered Design for Assistive Mobile Manipulation

Tiffany L. Chen[1], Matei Ciocarlie[3], Steve Cousins[3], Phillip Grice[1], Kelsey Hawkins[1], Kaijen Hsiao[3], Charles C. Kemp[1], Chih-Hung King[1], Daniel A. Lazewatsky[2], Adam Leeper[3], Hai Nguyen[1], Andreas Paepcke[3], Caroline Pantofaru[3], William D. Smart[2], and Leila Takayama[3]

***Abstract*— The Robots for Humanity project aims to enable people with severe motor impairments to interact with their own bodies and their environment through the use of an assistive mobile manipulator, thereby improving their quality of life. Assistive mobile manipulators (AMMs) are mobile robots that physically manipulate the world in order to provide assistance to people with disabilities. They present an exciting frontier for assistive technology, as they can operate away from the user, have a large dexterous workspace (due to their mobility), and not directly encumber their users. The cornerstone of this project is an ongoing, interactive design process with a quadriplegic user, Henry Evans, and his wife and primary caregiver, Jane Evans. Henry has been enabled, through the use of a PR2 robot, to scratch his own face, shave, fetch a towel from his kitchen, and hand out Halloween candy to trick-or-treating children at a local mall.**

I. INTRODUCTION

Henry Evans was left mute and quadriplegic by a brain stem stroke. Significant therapy has helped him regain movement of his head and one finger, which enables him to move a cursor using a head tracker and click a mouse button. In October 2010, Henry saw a TV interview where Professor Charlie Kemp from Georgia Tech showed research with a Willow Garage PR2, and immediately recognized that robots such as the PR2 could be used as assistive devices for people with severe motor impairments. Henry contacted our research team shortly thereafter, and kicked off the project described in the video, which he has named “Robots for Humanity”. Over the past year, the research team, Henry, and Jane have gathered four times (March, June, and October 2011, and February 2012) for multiple-day workshops to have Henry test robotic hardware and software tools, and to use feedback from Henry and Jane to iteratively improve on those designs and develop the next set of capabilities. Henry is excited about having a robot act as surrogate for his paralyzed body, and believes that thousands of other people with similar motor impairments could be similarly empowered.

Within the project, we are specifically targeting two research areas that will help determine the success of assistive mobile manipulators in the future. First, we want to understand how individuals with severe motor impairments can use these robots to effectively accomplish self-care tasks and household activities. By exploiting the capabilities of both the user and the robot to compensate for their respective impairments, we aim to develop tools that make the human-robot team far more capable than either individually. Second, we want to explore how mobile manipulators can most robustly assist the user given the large degree of variation and uncertainty in domestic environments. Since assistive mobile manipulators will be expected to operate in the unstructured homes or workplaces of the users, the robot must be able to interact with and around clutter, people, changing lighting conditions, and other confounding factors, all of which are notorious for defeating a robot’s autonomous capabilities.

Using a shared autonomy approach, our interfaces allow a user to provide semantic and domain knowledge as well as enhanced perceptual understanding that can compensate for the robot’s uncertainty. By designing smart interfaces, we can reduce the complexity of the control presented to the user, making the robot easier to use and the human-robot system more capable. Also, by keeping the user in the loop, the task’s semantic goals and constraints are better grounded, as they come directly from the person trying to perform the task. In this video, we present progress on two of our goals for robotic assistance: manipulation around the user’s head and face, and manipulation of remote objects in unstructured home environments.

II. ASSISTANCE WITH MANIPULATION NEAR ONE’S BODY

The first workshops have focused on the tasks of scratching and shaving, incrementally developing interfaces and controls that enable Henry to operate the robot more effectively and safely. When performing the scratching task, the robot holds a custom-designed, 3D-printed tool modeled after a back-scratcher. For the shaving task, a commercial electric shaver is used, modified with a handle suitable for

Authors are listed in alphabetical order by last name.

[1]T. Chen, P. Grice, K. Hawkins, C. Kemp, C. King, and H. Nguyen are with the Healthcare Robotics Lab, Georgia Institute of Technology, Atlanta, GA, USA. charlie.kemp at bme.gatech.edu, {tiffany.chen, phillip.grice, kphawkins, hai} at gatech.edu, aaking at hsi.gatech.edu

[2]W. Smart and D. Lazewatsky are with the Media and Machines Laboratory, Department of Computer Science and Engineering, Washington University in St. Louis, St. Louis, MO, USA. {wds, dlaz} at cse.wustl.edu

[3]M. Ciocarlie, S. Cousins, K. Hsiao, A. Leeper, A. Paepcke, C. Pantofaru, and L. Takayama are with Willow Garage, Inc., Menlo Park, CA, USA. {matei, cousins, hsiao, aleeper, paepcke, pantofaru, takayama} at willowgarage.com

the PR2's gripper and a microcontroller for switching the shaver on and off via software.

The first design gave Henry buttons to control the robot's base, arm, and head. A combination Cartesian and joint-space control scheme was provided that allowed Henry to move and orient the tool in small, discrete steps in the robot's reference frame. Although Henry was able to use this interface to scratch himself, it was difficult for him to perform complex movements quickly and effectively.

For the next workshop, the interface was modified to allow Henry to click on a live video display to select the 3D location with which to make contact. Using a Kinect sensor, the 3D position and surface normal of the clicked point were estimated, and the robot positioned the tool perpendicular to the surface a short distance away. From that position, a few modes of control were then available, including advancing or retreating along the normal, as well as arbitrary Cartesian control. Using this interface, Henry was able to move the tools to his face, and performed both scratching and shaving by moving his head against the tools.

To better control the orientation of the tool while moving between regions of Henry's head, the third workshop introduced a new controller that utilized an ellipsoidal coordinate system registered to the user's head. The robot attempts to keep the tool perpendicular to the surface of the ellipsoid, while providing buttons that allow the user to move tangent or perpendicular to the surface in incremental steps. For example, when positioned in front of the nose, the tool will point directly at the center of the face. If the user repeatedly clicks 'right', the tool will be moved around the face in a curve until the tool is positioned away from their right ear, pointing directly at it (toward the center of the ellipse).

Because of the length of the tools, the kinematics of the arm, and the size of the robot's base and Henry's wheelchair, placing Henry's face within the workspace of the arm is both critical and also difficult. Thus, in the fourth workshop, AR tags, attached to both sides of Henry's wheelchair, were used to better automate the robot's approach procedure. The PR2 approaches the tags by visual servoing using cameras in the forearms of the robot, which allows it to achieve a consistent and effective position for moving a tool around Henry's face.

III. ASSISTANCE WITH MANIPULATION OF OBJECTS

A separate interface is geared towards allowing Henry to manipulate objects remotely to accomplish tasks such as tidying up around the house, answering his front door, or fetching objects. This interface provides tools with varying levels of autonomy for navigation, perception, and manipulation. Tools with higher levels of autonomy can allow the user to carry out tasks or sub-tasks faster, while tools with lower levels of autonomy allow the user to take full control of the robot to accomplish arbitrary tasks for which no autonomous tools exist, or in case of failures.

For grasping objects, the robot can autonomously recognize or at least segment well-separated objects sitting on tables. The user can command the robot to grasp such objects in a fully-autonomous manner. For objects that the robot cannot recognize or segment, the user can still specify, in 6D, the final grasp pose for the robot gripper, and command the robot to autonomously execute the chosen grasp using collision-free motion planning. To perform more arbitrary manipulation tasks, or tasks where collisions may be unavoidable, the user can directly translate and rotate the grippers in Cartesian space using a rings-and-arrows control attached to each gripper.

For navigation, the robots autonomous capabilities allow it to navigate in a collision-free manner through free space. However, the robot's autonomous navigation capabilities prevent approaching too close to obstacles. Thus, to move right up to obstacles, or even push them around, the user can also select a final pose for the robot relative to a 3-D snapshot of the world, and have the robot drive there directly, open-loop. For even more direct control, the user can also drive the base using rate-controlled arrows.

Using this interface, Henry is able to perform complex tasks in his home such as the one shown in the video. Henry controlled the robot to drive from his living room to his kitchen, opened and closed a kitchen cabinet door to examine the contents, opened a drawer, removed a towel, and finally brought the towel back to his wheelchair in the living room. This task used both autonomous and open-loop tools for navigation, grasping, and arm movement. It was executed in a single continuous run, and succeeded on the first attempt. The same interface was used by Henry to complete the same user study performed by able-bodied users in [2], in which he grasped objects from a cluttered shelf, as shown in the video. Using a grasping interface with more autonomous assistance enabled both Henry and the other user study participants to grasp objects more quickly than when using a tool with more direct control, which demonstrates the potential benefits of providing autonomous assistance.

This interface was also used by Henry to grasp candy from a table to give to trick-or-treating kids at Halloween at a local mall, which is also featured in the video. Details about the interface for interactive manipulation can be found in [1].

IV. CONCLUSIONS

As seen in the video, our methods have enabled Henry to use the PR2 to scratch and shave himself, retrieve an object in his home, and begin to interact with other people through the robot. Remaining challenges include enabling Henry and Jane to use a PR2 in their home for longer durations, and evaluating our methods with other people with motor impairments. We are excited to address these challenges with the help of Henry and Jane Evans.

Videos and code associated with the project can be found at http://www.willowgarage.com/robotsforhumanity.

REFERENCES

[1] M. Ciocarlie, K. Hsiao, A. Leeper, and D. Gossow. Mobile manipulation through an assistive home robot. *IROS*, 2012.

[2] A. Leeper, K. Hsiao, M. Ciocarlie, L. Takayama, and D. Gossow. Strategies for human-in-the-loop robotic grasping. In *Proc. of Human-Robot Interaction (HRI)*, 2012.