Designing for Human Robot Interaction

As robot research matures, robot applications are being used by people who did not develop the system. For example, robots are cleaning the floors of many houses. Robots are also being deployed for disaster recovery and for diffusing explosive devices. With non-developer users, the interaction between robots and humans must be efficiently and effectively designed.

Our research in this emerging field of human-robot interaction (HRI) is aimed towards discovering design and interaction principles, building system level support for effective HRI, and defining new evaluation methods. Our research is tested in two primary application domains, urban search and rescue (USAR) and assistive technology (AT), both which require error free interaction.

The robot’s operator in a USAR situation is located at a distance from the robot. This creates a need for the interface to provide adequate situation awareness (SA), i.e. the knowledge of the robot’s current state and surroundings. In contrast, users are collocated with robots used for assistive technology interaction must focus on low-bandwidth input, as users may only be able to use a small set of switches.
Design of a USAR Interface

Situation awareness (SA) is critical to the successful operation of an unmanned vehicle. We have implemented a video-centric USAR system. The main focus of our interface is a video feed. A small mirrored video display simulates a rear-view mirror in the upper right.

Our interface utilizes many novel features such as the fusion of direct sensor information to increase situation awareness. Specifically, we combine laser and sonar information to indicate obstacles within a one-meter radius of the robot (shown directly below main video display) and map the environment during operation (shown upper left of main video display). We also fuse FLIR with video (shown in the main video display), which allows the operator to easily notice potential unseen victims.

Camera Placement for Remote Robot Operation

We have studied the impact of camera location and multi-camera fusion with real robots in an urban search and rescue task. Developers have tried a variety of cameras, lens types, and camera locations with different degrees of success to achieve better situation awareness. We designed experiments that isolated the camera placement and number to learn the optimal characteristics for maintaining good situation awareness.

On our ATRV-JR robot, we have mounted two video cameras: one on the front and the other on the rear of the robot. Using the rear camera, we have created an Automatic Direction Reversal (ADR) mode. We made it possible to reverse the robot’s travel direction in a way that makes the front and rear of the robot virtually identical from the user’s perspective. When the user switches to the rear (or front) camera view, the interface automatically remaps the joystick drive command and the display of range information accordingly. This design allows a user to drive into narrow confines without having to back out; the user can simply select the opposite camera view and drive out as if moving forward. We found that operators had fewer hits when they had the two camera views available to them than when they only had a front facing camera.

Our collaborators at Swarthmore College mounted two front cameras on their robot: one pointing straight ahead and the other angled down to show the robot in the video image. Operators hit obstacles in the environment fewer times when they could see the robot in the camera’s view. We also found that some subjects in our front and rear camera study developed the strategy of tilting the camera all the way down to see the front bumper; these subjects had fewer collisions with the environment.

The operator’s situation awareness is improved by both permitting the operator the option of viewing the robot within its environment and, especially for asymmetric robots, given the operator quick access to a rear view. Our results should have an immediate impact on the design of robots for remote operation, especially within the USAR and explosive ordnance disposal (EOD) communities. In these two remote robot application domains, obtaining and maintaining good situation awareness is critical to the task at hand.

Adjusting Robot Autonomy

In addition to addressing situation awareness, we investigate robot autonomy. Autonomy levels range from tele-operation (remote control car) to fully autonomous (iRobot's Roomba). The level of HRI varies along this spectrum.

Currently, robot systems operate in discrete levels of autonomy. It is easy to imagine situations where a system that could move up or down the autonomy continuum would be useful. Human operators may wish to override the
robot’s decision, or the robot may need to take over additional control during a loss of communication.

We define sliding scale autonomy as the ability to create new levels of autonomy between existing, pre-programmed ones. We have designed a sliding scale autonomy system. It dynamically combines human and robot inputs and suggests the optimal robot autonomy level.

**Evaluation Methodologies**

Inspired by the human-computer interaction (HCI) and computer-supported cooperative work (CSCW) communities, we have worked to develop effective HRI techniques, HRI design guidelines, and HRI evaluation techniques. We focus on urban search and rescue (USAR) because it deals with safety-critical and time-critical situations for the victims, operators, and rescue robots.

Over the years, we have evaluated the performance of a dozen systems designed for USAR. We have investigated the effectiveness of techniques for making human operators aware of the robot and its environment, performing usability testing specifically to probe situation awareness acquisition and maintenance.

Most problems encountered when navigating a robot have resulted from the human’s lack of awareness of the robot’s location, surroundings, or status. We found on average that 30% of overall run time was spent acquiring situation awareness.

Based on these finding, we developed guidelines for designing HRI in robots, including enhancing awareness by providing a dynamically generated map, lowering cognitive load by fusing sensor information, increasing efficiency by minimizing the number of windows, and providing suggestions of appropriate robot autonomy levels.

We have also developed a SA analysis technique called LASSO (location, activity, surroundings, status, overall mission awareness). LASSO allows for comparison of HRI designs for different situation awareness components.
Our Collaborators
- MITRE (Jill Drury)
- Swarthmore College (Bruce Maxwell)
- National Institute of Standards and Technology (Elena Messina, Adam Jacoff, Brian Weiss, Jean Scholtz)

Related Links
- UMass Lowell Robotics Lab
  http://www.cs.uml.edu/robots
- NIST USAR Testing
  http://www.isd.mel.nist.gov/projects/USAR/

Selected Publications


