Improving Human-Robot Interaction for Remote Robot Operation

Holly A. Yanco, Michael Baker, Robert Casey, Andrew Chanler,
Munjal Desai, Dan Hestand, Brenden Keyes, and Philip Thoren

University of Massachusetts Lowell, Computer Science Department
One University Avenue, Olsen Hall
Lowell, MA 01854
{holly, mbaker, rcasey, achanler, mdesai, phestand, bkeyes, pthoren}@cs.uml.edu

Introduction

We have been investigating ways to improve human-robot interaction (HRI) and situation awareness (SA) in urban search and rescue (USAR). In this task, a human directs the navigation of a remotely located robot using an interface that provides controls and status information. In this paper, we discuss the many facets of our work aimed at improving HRI for remote robot operation.

System Design

Robot Platform

Our robot platform is an iRobot ATRV-Jr research robot. The robot has a SICK laser rangefinder, positional sensors, and a full sonar ring (26 sonars) that can detect obstacles on all sides. We have added front and rear pan-tilt-zoom cameras and a lighting system (see figure 1).

Presentation of Information

In robotic systems developed for urban search and rescue, information overload can cause operator disorientation and missed detection of victims. In most systems, multiple sensor modalities are present on the robot, and the operator is presented with multiple displays of information requiring attention refocus.

Our system design is a result of our HRI studies in USAR (see, for example, [Yanco and Drury 2004; Scholtz et al. 2004; Yanco et al. 2004]). A major influence on our design philosophy comes from the observation that users of USAR interfaces become so absorbed in the video display that they ignore all other information on the interface. We exploit this behavior in our design by placing important information on and around the main video display to make it difficult for users to overlook. A full description of the work can be found in [Baker et al. 2004].

We have also been investigating how we can overlay FLIR and other sensor data such as levels of carbon dioxide and direction of the primary sound source on the video display [Hestand and Yanco 2004]. Our results indicate that layering sensor modalities into an integrated image has potential to increase the likelihood of detecting hidden or non-obvious scene features.

Interface Controls

Our control system consists of a specially modified keyboard, and a joystick. The keyboard can be used to select and operate all functions of the interface; each key is labeled and controls a single function. We are continuing to investigate other control methods, including haptics.

Suggestion System

The idea of interface suggestions is not new to the human-computer interaction (HCI) community, but they have not been used in HRI interfaces. The suggestion system began as a way to suggest appropriate autonomy modes, allowing use to investigate when it might be appropriate for the robot to switch modes automatically. We had observed in our studies that users did not use different autonomy modes effectively; the suggestion system was designed to encourage judicious mode switching, which increases task efficiency while teaching the user about the robot's autonomous capabilities. The suggestion system is described in [Baker and Yanco 2004].

Automatic Direction Reversal (ADR)

We have used the rear camera on our robot to create a unique and useful feature that we call "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 commands and display of range information accordingly. This means that the user can drive the robot into narrow confines without having to back out; the user can simply select the opposite camera view and drive out normally. This is a safer, more efficient way to navigate the robot out of tight spaces than backing out or physically turning the robot around.

Sliding Scale Autonomy

There is a continuum of robot control ranging from teleoperation to full autonomy; the level of human-robot interaction, measured by the amount of intervention required, varies along this spectrum. Constant interaction is required with teleoperation, where a person is remotely controlling a robot. Less interaction is required as the robot has greater autonomy. Operating in the space between teleoperation and full autonomy is referred to as shared control. Additional definitions of autonomy can be found in [Huang et al. 2003] and [Goodrich et al. 2003].

We define sliding scale autonomy as the ability to create new levels of autonomy between existing, pre-programmed autonomy levels. Most autonomous mobile robot systems have discrete autonomy modes modeled according to their application. However, many occasions require a combination of available autonomy modes, which is not possible. In such situations, sliding scale autonomy can be used to provide intermediate autonomy levels on the fly, thus providing a great deal of flexibility and hence allowing optimum usage of the system.

We have designed a sliding scale autonomy system which has shown that it has the ability to dynamically combine human and robot inputs, using a small set of variables: force field, user speed, robot speed, speed contribution, speed limiter and obstacle avoidance. These variables were selected by examining current discrete autonomy levels and determining how they differed. We expect to add new variables as work continues.

We believe that this type of system could be particularly useful when a robot needs assistance. Instead of stopping and requiring user intervention when the robot is unable to determine what to do, the robot could start to shift some autonomy to the user as it begins to recognize that the situation is becoming more difficult. This should prevent the usual problem of a human operator needing to take on full control of the robot in the worst possible situations.

Conclusions

We have created a robot system for HRI that provides more useful information to the operator while reducing their cognitive load. In user testing, we have seen the built-in autonomy modes utilized successfully. We have enhanced situation awareness by use of an additional camera, better map placement, and more comprehensible sensor information. In doing so, we have virtually eliminated rear hits while still keeping the interface intuitive. Through these tests, we have confirmed many of our original hypotheses. We have also taken away many lessons on how to improve our interface in the future.

Figure 1: The robot platform.

Acknowledgements

Thanks to Doug Few and David Bruemmer of INEEL for their autonomy mode system. This work is supported in part by NSF IIS-0308186, NSF IIS-0415224 and NIST 70NANB3H1116.

References

Baker, M., R. Casey, B. Keyes and H,A. Yanco, 2004. "Improved interfaces for human-robot interaction in urban search and rescue." *Proceedings of the IEEE Conference on Systems, Man and Cybernetics*, October.

Baker, M. and H.A. Yanco, 2004. "Autonomy mode suggestions for improving human-robot interaction." *Proc IEEE Conf on Systems, Man and Cybernetics*, October.

Goodrich, M.A., J.W. Crandall, and J.L. Stimpson, 2003. "Neglect tolerant teaming: issues and dilemmas." *Proc AAAI Spring Symposium on Human Interaction with Autonomous Systems in Complex Environments.*

Hestand, D. and H.A. Yanco, 2004. "Layered sensor modalities for improved feature detection." *Proc IEEE Conference on Systems, Man and Cybernetics*, October.

Huang, H.-M., E. Messina, and J. Albus, 2003. "Toward a generic model for autonomy levels for unmanned systems (ALFUS)." *Proc. PerMIS.*

Scholtz, J., J. Young, J.L. Drury and H.A. Yanco, 2004. "Evaluation of human-robot interaction awareness in search and rescue." *Proc. IEEE International Conference on Robotics and Automation (ICRA)*, New Orleans, April.

Yanco, H.A., and J.L. Drury, 2004. "'Where am I?' Acquiring situation awareness using a remote robot platform." *Proc IEEE Systems, Man and Cybernetics.*

Yanco, H.A., J.L. Drury and J. Scholtz, 2004. "Beyond usability evaluation: analysis of human-robot interaction at a major robotics competition." *Journal of Human-Computer Interaction*, 19 (1 and 2): 117 - 149.