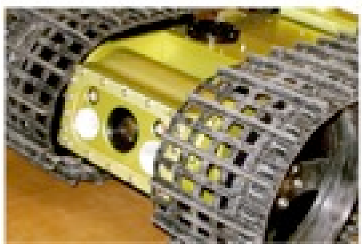
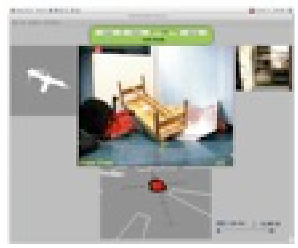
Robot Interaction @ UMass Lowell

UMass Lowell Robotics Lab
Department of Computer Science
http://www.cs.uml.edu/robots





Designing for Human-Robot Interaction

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

The UMass Lowell Robotics Lab's research in this emerging field of human-robot interaction (HRI) is 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. Both of these real world domains require error free interaction.

These domains have specific requirements and diverse human-robot interaction needs. In a USAR situation, the operator is located some distance from the robot. This creates a need for the interface to provide adequate situation awareness, i.e. the knowledge of the robot's current state and surroundings. In contrast, users are collocated with robots used for assistive technology interaction which must focus on low-bandwidth input, as users may only be able to use a small set of switches and input devices.

UMass Lowell Robotics Lab

The Robotics Lab was founded by Dr. Holly Yanco in 2001. Research focuses on human-robot interaction (HRI), which includes interface design, robot autonomy, computer vision, and evaluation methods. Application domains include assistive technology (AT) and urban search and rescue (USAR). The Robotics Lab also has an active community partnerships program, working with K-12 students.

Research in the lab is funded by the National Science Foundation (IIS-0308186, IIS-0415224, IIS-0546309, IIS-0534364, SES-0623083, CNS-0540564) and the National Institute of Standards and Technology (70NANB3H1116). Dr. Yanco received an NSF Career Award in 2005.

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Camera Placement for Remote Robot Operation

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

Our ARTV-JR is equipped with two pan-tilt-zoom cameras, one facing forward and one facing backward. Appropriately placed cameras can enhance an operator's awareness of the remote robot's surroundings.

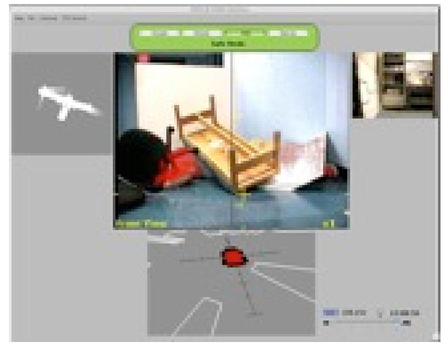
On our ATRV-JR robot, we have mounted two video cameras: one on the front and one on the rear of the robot. Using the rear camera, we have created an Automatic Direction Reversal (ADR) mode. This made it possible to reverse the robot's travel direction in a way that makes the front and rear of the robot 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. The design allows a user to drive into narrow confines without having to back out. The user simply selects the opposite camera view and drives 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 had only 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, giving the operator quick access to a rear view. Our results will have an immediate impact on the design of robots for remote operation, especially within the USAR and explosive ordnance disposal (EOD) communities.

Design of an Urban Search and Rescue Interface

Obtaining and maintaining situation awareness (SA) is critical to the successful operation of an unmanned vehicle. The UMass Lowell Robotics Lab has implemented an interface for an urban search and rescue (USAR) robot. The main focus of our interface is a video feed. A second, small mirrored video display simulates a rear-view mirror in the upper right corner of the interface.



UML's USAR interface identifies a hidden victim, shown in red in the main video display. An augmented interface increases the user's situation awareness during remote operation.

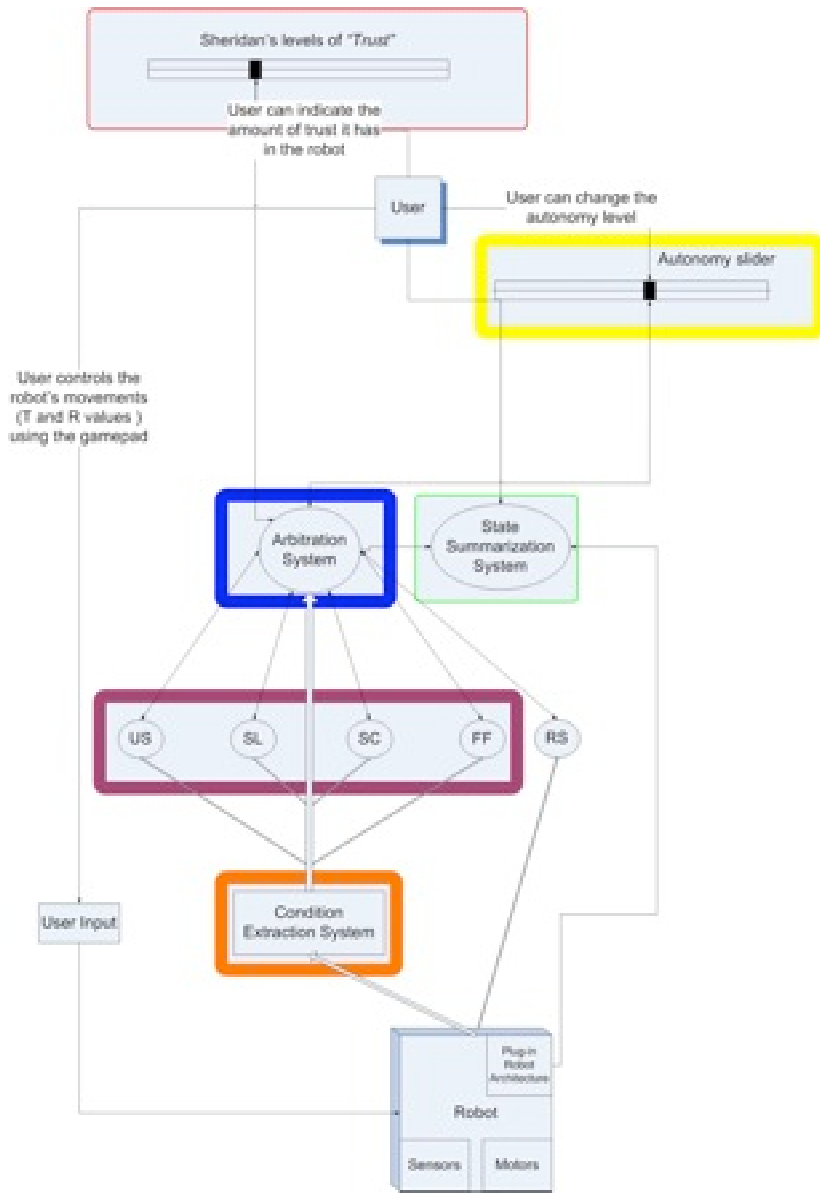
Our interface uses many novel features, including the fusion of direct sensor information to increase situation awareness. Specifically, we combine sonar and laser ranging information to indicate obstacles close to the robot (shown directly below the main video display) and to map the environment during operation (shown to the left of main video display). We also fuse thermal information with video (shown in the main video display), which allows the operator to easily notice hidden victims.

Adjusting Robot Autonomy

In addition to addressing situation awareness, the UMass Lowell Robotics Lab has investigated robot autonomy. Autonomy levels range from teleoperation (remote control car) to fully autonomous (iRobot's Roomba). The level of interaction varies along this spectrum.

Currently, robot systems operate using 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 autonomy and 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.



A flow diagram of UML's implementation of sliding scale robot autonomy. The Condition Extraction System (orange) collects information, processes it and generates conditions. Conditions are passed to the System Variable Agents (purple) that generate suggestions for the system variables. Suggestions are then passed on to the Arbitration System (blue) where they can be accepted, ignored or modified. The level of robot autonomy ranging from teleoperation to full autonomy is set using the Autonomy Slider (yellow).

Evaluation Methodologies

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

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

Most robot navigation problems have resulted from the operator's lack of awareness of the robot's location, surroundings or status. We found on average that 30% of overall run time are spent acquiring situation awareness.

Based on these findings, we developed awareness enhanced HRI in robots by providing a dynamically generated map, lowering the cognitive load with fused sensor information, increasing efficiency with a minimal number of windows, and suggesting appropriate autonomy levels.

We have also developed a situation awareness analysis technique called LASSO (location, activity, surroundings, status, overall mission awareness). LASSO allows for comparison of HRI designs for different SA components.

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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

H. A. Yanco and J. L. Drury. "Rescuing Interfaces: A Multi-Year Study of Human-Robot Interaction at the AAAI Robot Rescue Competition." *Autonomous Robots*, to appear.

J. L. Drury, B. Keyes and H. A. Yanco. "LASSOing HRI: Analyzing Situation Awareness in Map-Centric and Video-Centric Interfaces." *Second Annual ACM/IEEE Conference on Human-Robot Interaction*, March 2007.

H. A. Yanco, M. Baker, R. Casey, B. Keyes, P. Thoren, J. L. Drury, D. Few, C. Nielsen and D. Bruemmer. "Analysis of Human-Robot Interaction for Urban Search and Rescue." *Proceedings of the IEEE International Workshop on Safety, Security and Rescue Robotics*, August 2006.

B. Keyes, R. Casey, H. A. Yanco, B. A. Maxwell and Y. Georgiev. "Camera Placement and Multi-Camera Fusion for Remote Robot Operation." *Proceedings of the IEEE International Workshop on Safety, Security and Rescue Robotics*, August 2006.

M. Desai and H. A. Yanco. "Blending Human and Robot Inputs for Sliding Scale Autonomy." *Proceedings of the 14th IEEE International Workshop on Robot and Human Interaction Communication*, August 2005.

J. L. Drury, H. A. Yanco and J. Scholtz. "Using Competitions to Study Human-Robot Interaction in Urban Search and Rescue." *ACM CHI Interactions*, pp. 39-41, March/April 2005.

M. Baker and H. A. Yanco. "Autonomy Mode Suggestions for Improving Human-Robot Interaction." *Proceedings of the IEEE Conference on Systems, Man and Cybernetics*, October 2004.

H. A. Yanco and J. L. Drury. "'Where Am I?' Acquiring Situation Awareness Using a Remote Robot Platform." *Proceedings of the IEEE Conference on Systems, Man and Cybernetics*, October 2004.

H. A. Yanco and J. L. Drury. "Classifying Human-Robot Interaction: An Updated Taxonomy." *Proceedings of the IEEE Conference on Systems, Man and Cybernetics*, October 2004.

J. Scholtz, J. Young, J. L. Drury and H. A. Yanco. "Evaluation of Human-Robot Interaction Awareness in Search and Rescue." *Proceedings of the IEEE International Conference on Robotics and Automation*, April 2004.

J. L. Drury, J. Scholtz and H. A. Yanco. "Applying CSCW and HCI Techniques to Human-Robot Interaction." *Proceedings of the CHI 2004 Workshop on Shaping Human-Robot Interaction*, April 2004.

J. L. Drury, D. Hestand, H. A. Yanco and J. Scholtz. "Design Guidelines for Improved Human-Robot Interaction." *Proceedings of CHI 2004*, Poster Presentation, April 2004.

H. A. Yanco, J. L. Drury and J. Scholtz. "Beyond Usability Evaluation: Analysis of Human-Robot Interaction at a Major Robotics Competition." *Journal of Human-Computer Interaction*, Volume 19, Numbers 1 and 2, pp. 117-149, 2004.

J. L. Drury, J. Scholtz and H. A. Yanco. "Awareness in Human-Robot Interactions." *Proceedings of the IEEE Conference on Systems, Man and Cybernetics*, October 2003.

H. A. Yanco. "Designing Metrics for Comparing the Performance of Robotic Systems in Robotics Competitions." *Proceedings of the IEEE Conference on Control Applications Workshop on Measuring Performance and Intelligence of Intelligent Systems*, September 2001.