Human-Robot Interaction Through a Distributed Virtual Environment

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The deployment of large, mobile sensor networks presents a wide range of problems, including 1) effectively communicating the important information to a user (or small set of users) without inundating him/her with irrelevant data, 2) allowing the user to affect the deployment of the network in an intuitive manner, and 3) making this interaction available to users that are located in the field. We are addressing these issues in search-and-rescue and reconnaissance domains by developing a prototype human interface architecture that includes two modes of visual interaction (panoramic image- and virtual reality-based), and speech input and output.

The user interface is presented with either a desktop computer or a fully-portable, wearable computing system (Xybernaut MA IV). The latter is equipped with a three-axis gyroscopic head tracking devicethat allows the user to employ head movements to change display perspective. The 3D virtual environment (Amstutz and Fagg, 2002) presents a coarse-level representation of the state of the real environment, including: a map of the space (walls, etc.), the location and orientation of the robots, markers that indicate locations at which panoramic images have been gathered, and the virtual location of other users of the system. Through this interface, the user is able to explore the spatial configuration of the environment, engaging her natural abilities to construct internal cognitive maps of the space. Detailed imagery is presented through the panoramic image viewing system. These images are captured from a robot-mounted camera equipped with a panoramic lens or are constructed through a mosaicing process. Once a panoramic image is gathered by a robot, a corresponding icon is presented in the virtual environment. This enables the user to asynchronously select and view the panoramic image at a time that is appropriate for the task.

The users may be involved in the control of the mobile robots at two different levels. At the first level is a "safe driving" mode in which a user may teleoperate the robot in terms of left/right forward/backward commands. The controller interprets these commands in the context of the local map to ensure that a collision does not occur and will automatically guide itself around obstacles. Users may also specify the goal position for robots from within the 3D virtual environment (e.g., "come to **this** location"). Given this goal information, a map of the environment, and information derived from a local sonar map, the robots employ a harmonic-function based path planning approach that ensures a certain degree of clearance from objects in the environment. Once a goal is specified, the path planner and robot controller take on the responsibility for moving the robot; the user may attend to other subtasks. The robots employ the Player/Stage support model for sensing, control and simulation (Gerkey et al., 2001). Thus, many robots may be connected into the system dynamically, and the real robots may be easily replaced with simulations for the purposes of large-scale testing.

In continuing work, we are focused on the 1) event-based, multi-modal reporting of state information by the robots (e.g., indicating that a task is complete or that help is needed); 2) evaluating the effectiveness of various components of the interface in supporting search-and-rescue tasks (especially when many robots are involved); 3) allowing users to interact with hierarchies of resources; 4) allowing users to interact with robots that manipulate the world (in particular, humanoid-class robots); and 5) projection of other forms of live data into the virtual environment (e.g., information about moving subjects).

This work was supported by NSF #EIA 9703217 (with REU supplement), DARPA/ITO #DABT63-99-1-0022 (SDR) and DARPA/ITO #DABT63-99-1-0004 (MARS). The authors wish to also thank Xybernaut Corporation for their support of this work.

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