Undergraduate Research Project: Collaborative Interfaces for USAR Robots

In environments too remote or too dangerous for human exploration, robots that collaborate with human operators provide an exciting alternative. Good decisions must integrate the robots' perceptions with the navigational and cognitive skills of both humans and machines. This project involves development of an interface for shared decision making in human/multi-robot teams.

The short-term goals of our research are to identify features of Human-Robot Interaction (HRI) systems that impact the performance of human/multi-robot teams. We consider a number of questions, such as: What information is needed by humans and robots to make decisions? How should shared information be communicated to team members in real-time?

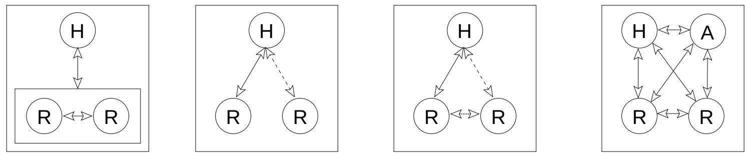
1 Background

Human-Robot Interaction supports collaborative activities by humans and robots to achieve shared goals. Typical HRI research concentrates on the development of software and/or hardware to facilitate a wide range of tasks. These include robots maneuvering in physical spaces, either designed for humans (e.g., [18]) or unfit for humans (e.g., [21]); humans programming complex robots (e.g., [24]) or different types of simple robots (e.g., [3]); robots cooperating with human partners (e.g., [4, 8, 29, 30]) and with other robots (e.g., [7, 19, 20, 26]); and user interfaces for communicating with robots (e.g., [17, 23]). Deployed HRI applications include cleaning [13], helping the elderly [27], assisting first responders in search and rescue tasks [6], and de-mining in military settings [10].

There are three main categories of control architectures for human-robot systems [12]: *fully autonomous*, where robots make decisions and control their actions on their own; *directly controlled*, where robots are driven by human operators; and *mixed-initiative* [5, 15], where robots share decision-making with human users. Mixed initiative approaches include: *adjustable autonomy*, which permits dynamic transfer of control from human to robot and vice versa (e.g., [11, 25]); and *collaborative control*, which offers a dialog-based architecture to "discuss" decisions in real-time (e.g., [9]). Other examples of mixed-initiative systems include the work of Adams *et al.* [1], who have developed an affect-based architecture, and Hong *et al.* [14], who employ statistical techniques to infer missing information in human-robot communication.

Yanco and Drury [31] established a useful feature-based taxonomy for HRI systems, which includes *levels of autonomy/intervention*; *human-robot ratio*; *time/space classification*; *composition of robot teams*; and *level of shared interaction*. Autonomy versus intervention is how much operational time each autonomous robot and intervening human has the initiative. The two levels are expressed as percentages that sum to 100%. The human-robot ratio describes the number of players in the system. Time/space classification indicates whether interactions between team members are synchronous or asynchronous and whether or not team members are physically collocated. Composition of robot teams specifies whether all robots are the same type (homogeneous) or not (heterogeneous). Finally, the level of shared interaction characterizes the flow of information and commands between human and robot team members. As illustrated in Figure 1a, the human can send one message to all the robots collectively, or, as shown in Figures 1b-1d, to individual robots.

We are studying mixed-initiative human-robot interfaces for exploration in unmapped constrained physical space. Within such teams, *coordination*—the desired result of shared decision-making—is an open area of research. Nourbakhsh *et al.* [22] eloquently express one of the primary issues: "Most systems implemented on robots elicit emergent behavior wherein individual robots follow simple coordination rules, without any explicit teamwork models or goals. This breaks down when a team includes people because the robots can't explain their actions and their role as a team player."



a. one human, robot team (from [31]) *b. one human, multiple robots (from [31])* *c. one human, multi-robot team* *d. one human, multi-agent, multi-robot team*

Figure 1: Levels of shared interaction. Note that although only two robots are depicted in each drawing, they should be interpreted as "two or more" robots. Also note that the single A shown in the fourth figure indicates the set of agent-based Advisors.

2 Project description

The undergraduate research project will focus on design and implementation of an HRI interface to support experiments in collaborative decision-making. The high-level design of the test bed is illustrated in Figure 1d. The physical equipment for the test bed resides in the Brooklyn College Agents Lab. It includes a $4' \times 8'$ *confined space test arena* for Urban Search and Rescue (USAR), developed by the National Institute for Standards and Technology (NIST) [28], as shown in Figure 2a; multiple small robots with various sensing capabilities, as shown in Figure 2b; an external computer hosting a "live" agent-based simulator; and a *user interface* that enables remote interaction by the human operator. A fully-connected network will be designed for communication among team members, but experience with real robots shows that signals drop out and the system architecture must be robust to a range of failures. The "live" agent-based simulator will contain virtual agents representing each physical robot and will position the agents, in real-time, according to sensor data received from the robots (e.g., [2, 16]).

a. USAR confined space arena b. Scribbler and Surveyor robots

Figure 2: Test arena and robots (Brooklyn College Agents Lab).

The undergraduate researchers engaged in this project will cooperatively design and implement the interface. This will include the following:

- adaptation of existing drivers for a range of small robot platforms,
- adaptation of an existing "live" simulator, and
- design and implementation of a new user interface for a human operator to receive input from and send commands to multiple robots.

The existing drivers are written in C/C++ and the existing simulator uses Open GL. Our development environment is Linux-based. Students should have strong programming skills and will learn how to use them in a dynamic application environment.

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