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Human-Robot Collaboration for Remote Surveillance

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Abstract

The demonstration presents an application of multiagent systems and wireless networking to remote robot-based surveillance.

Introduction

In current practice, robotic surveillance is accomplished through human tele-operation, with little or no autonomous capability. While having the advantage of keeping the human operator out of harm's reach (*e.g.* in the domains of search and rescue and bomb detection), tele-operation provides little in the way of manpower reduction: sometimes two or three humans are required for each robot (movement control, payload control, protection, *et cetera*). The goal of our work is to give more autonomy to the robotic agents such that any member of the team can successfully task multiple robots without cognitive overload.

Consider a group of human police officers and robots working together to perform a street patrol. Each robot is controlled by a software agent, and additional agents work together to coordinate the interaction between the humans and the robots. In the case of an emergency, such as the discovery of a suspicious object, the robots may be alerted and employed to investigate without putting the officers in danger. In all other instances the robots should be unobtrusive and require little human oversight. The agents controlling the robots can perform simple tasks like waypoint navigation, following and obstacle avoidance, alleviating the human controllers from these time- and attention-consuming activities. Note that, in this scenario, tele-operation would require constant visual feedback from the robot, which can either be dangerous or expensive (in terms of network bandwidth) to facilitate. These liabilities are mitigated in our demonstration by the reduced need for the operators attention and visual field.

Demonstration

For this demonstration, the system is built on handheld computing devices—tablets and Personal Digital Assistants (PDAs)—communicating wirelessly over a mobile, ad hoc, WiFi network (MANET). Such networks enable significant data exchange without infrastructure such as wires or access points, adapt to changing conditions such as host movement, and operate over moderate geographic distances, however, such networking presents challenges distinct from traditional networking, such as high latency, data loss, and frequent connectivity disruptions. The mobile devices' and robots' network—which, weather permitting, will be located outdoors—is bridged over a CDMA-based cellular network to a command center in the demonstration arena. Both the humans and robots have essentially equivalent computing devices; all are equipped with 802.11 wireless cards and GPS receivers. Attendees may observe live video streams from the cameras on the robots (as in Figure 2), re-task the robots via a map overlay, communicate with the remote humans via their PDAs, and also take complete control over the remote robots via tele-operation. Should the robots and PDA-equipped humans be forced indoors, the demonstration proceeds similarly, however, the robots navigate using solely dead reckoning (as opposed to GPS) and their network is bridged over WiFi.

Figure 1: Robot following PDA-enabled humans in the surveillance scenario.

Screenshots of the PDA interface are given in Figure 3. Here, a group of three humans (represented by the green and blue nodes) are on a patrol, with a robot autonomously following one of the humans (the robot may be tasked to follow any of the humans). The center human in Figure 3(a) sees a suspicious vehicle, annotating it on the map. Any of the humans could have made such an annotation at any time. The annotation is then displayed on all of the PDAs. This event triggers the command center to select a robot for possible in-

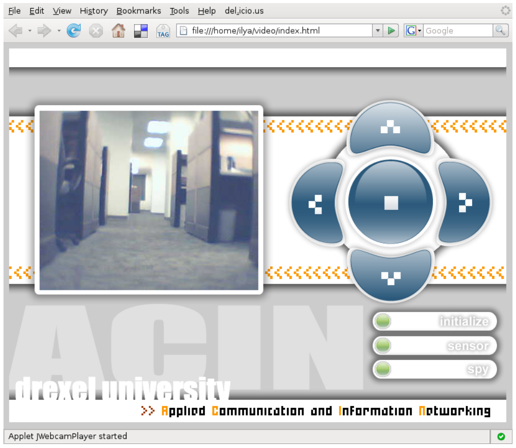
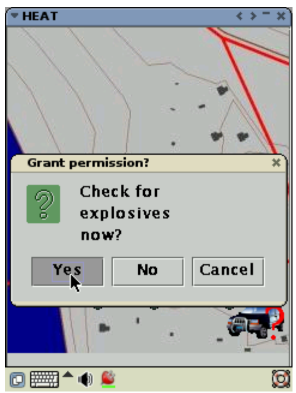


Figure 2: Video streaming from the robot to the command center.

(a) A human discovers a suspicious vehicle, reporting it on the PDA.



(b) The robot asks permission of the commander (via her PDA) to investigate.

Figure 3: PDA interface for the humans.

vestigation. The commander—a role that is assigned to one of the humans but likewise could be any human—is then prompted in Figure 3(b) by the robot to give it permission to re-task for inspecting the vehicle. When the commander gives permission, a route to investigate the vehicle is planned and executed. At any time, the human controller at the command center, having a greater level of situational awareness, can also override the tasking. In the event of a network outage or lack of manpower, however, the entire operation may be completed without a human at the command center.

Technical Content

The primary artificial intelligence components of this demonstration are the agents which act on behalf of the robots to lessen the need for micromanagement from the human commander. The agents are modeled using the Soar Cognitive Architecture (Laird and Rosenbloom 1996) and coordinated plans are created within the command center's Intelligent Control Framework (ICF) developed by Soar Technology. ICF maintains situational awareness and provides the command center interface with it's command and display capabilities. ICF also provides task management and dialog capabilities. In the event that, due to loss of network connectivity, the robots are no longer able to be tasked by the ICF, however, they can reason and act (possibly sub-optimally) on their own. The network and agent framework is provided through the Secure Wireless Agent Testbed (SWAT) (Sultanik et al. 2003) and Optimized Link State Routing (OLSR) (Clausen and Jacquet 2003).

Conclusion

This relatively simple scenario demonstrates a number of innovative capabilities. The robot functions more as a part of the team rather than as a tool controlled by a single user. It does not require special attention from the humans in the field. The robot interacts with the humans in a way that is natural for the humans and does not require significant training. The robot demonstrates interruptible tasking by offering to perform a new task while another is in progress, returning to its previous task after the new task is complete. The robot relies on situational awareness provided by the sensory and reasoning capabilities of the entire team rather than requiring advanced sensory capabilities of its own to navigate and perform its tasks. Finally, the combined use of PDAs, GPS and MANET technologies enable shared situational awareness and distributed control of the robot.

The demonstration presents an application of multiagent systems to remote robot-based surveillance. Requirements of this application such as partial decentralization, coordination, and robustness to unreliable networking make it a natural fit for such an approach. Novel aspects of this system include the integration of many facets of artificial intelligence with advanced networking techniques that are required for real-world situations. The goals of this demonstration system are both to present initial work on meeting these challenges as well as to provide a platform to explore and develop improved solutions.

Acknowledgements

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