Human Augmentation for Search and Rescue

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The Big Picture

We consider search and rescue applications in which heterogeneous groups of agents (humans, robots, static and mobile sensors) enter an unknown building and disperse while following gradients in temperature and concentration of toxins, and looking for immobile humans. The agents deploy the static sensors and maintain line of sight visibility and communication connectivity whenever possible. Since different agents have different sensors and therefore different pieces of information, communication is necessary for tasking the network, sharing information, and for control.

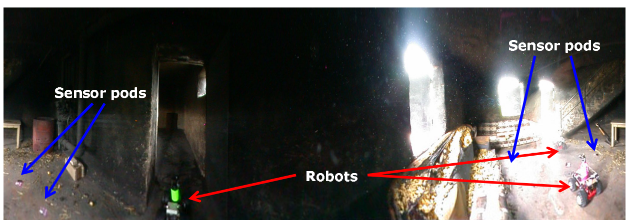

Figure 1: An ad-hoc network of robots and Mote sensors deployed in a burning building at the Allegheny Fire Academy, Aug 23, 2002 (from an experimental exercise involving CMU, Dartmouth, and U. Penn)

Our heterogeneous teams of agents constitute distributed adaptive sensor networks and are well-suited for tasks in extreme environments, especially when the environmental model and the task specifications are uncertain and the system has to adapt to it. A collection of agents can track the motion of a source, for example a moving vehicle, it can guide the movement of a user (robot or human), or it can focus attention over a specific area, for example a fire to localize its source and track its spread. Applications of this technology cover search and rescue for first responders, monitoring, surveillance, and infrastructure protection.

We combine networking, sensing, and control to control the flow of information in search and rescue in unknown environments. Specifically, we examine (1) information flow across a sensor network for delivering the most relevant and current information to its consumer, maintaining current maps, and team localization; (2) using the feedback from the sensor network to control the autonomous mobile agents for placing sensors, collecting data from sensors, and locating targets; and (3) delivering the information gathered from the sensor network (integrated global picture) to human users.

Information Flow

Sensors detect information about the area they cover. They can store this information locally or forward it to a base station for further analysis and use. Sensors can also use communication to integrate their sensed values with the rest of the sensor landscape. Users of the network (robots or people) can use this information as they traverse the network.

We have developed distributed protocols for two tasks in which a distributed sensor field uses sensory data to guide a user across the filed. In the first application, the sensors record danger levels such as high temperature. The safest path across the sensor field is then computed and updated incrementally, as the danger levels change. In the second application, we use this system to guide a firefighter or robot to a victim trapped in smoke; we then guide the people out. In this application, a sensor triggers (for example by user contact). A path from this sensor to an outside base station is then computed. An agent interacts with the sensors one-by-one, each time receiving the next direction of movement from the sensor field.

Control of a Network of Robots

Each robot must use partial state information derived from its sensors and from the communication network to control in cooperation with other robots the distribution of robots and the motion of the team. We treat this as a problem of formation control where the motion of the team is modeled as an element of a Lie group, while the shape of the formation is a point in shape space. We seek abstractions and control laws that allow partial state information to be used effectively and in a scalable manner.

In fire fighting and search and rescue, robots move to acquire information and to provide situational awareness for fire fighters. Information from on-board vision sensors and from an organic (stationary) sensor network is used to guide this process. Cooperative localization schemes enable the underlying computations to be decentralized. We have demonstrated the use of such cooperative control schemes and their benefits to target identification and mapping, and cooperative manipulation tasks, and are currently studying the performance of these schemes in environments with poor visibility.

User Feedback

When robots or people interact with the sensor network, it becomes an extension of their capabilities, basically extending their sensory systems and ability to act over a much large range. We have developed software that allows an intuitive, immersive display of environments. Using, panoramic imaging sensors that can be carried by small robots into the heart of a damaged structure, the display can be coupled to head mounted, head tracking sensors that enable a remote operator to look around in the environment without the delay associated with mechanical pan and tilt mechanisms.