

Blue Swarm II

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Abstract

This paper discusses the Blue Swarm II, Utah State University's entry in the 2001 Urban Search and Rescue competition. The design of the swarm is discussed, along with the problems encountered. Our plans for the 2002 competition are also discussed.

The Swarm

The Utah State University entry in this year's Urban Search And Rescue (USAR) competition was Blue Swarm II. Blue Swarm II is the follow-on to Blue Swarm I, which was an analog-controlled swarm. Blue Swarm II was made up of five modified *Red Fox* remote controlled cars. The *Red Fox* cars were selected because of their low cost (less than \$10 each) and because they have two motors, so differential steering can be used. The remote control was cut off of the car and the motor wires were hooked up to an H-bridge integrated circuit. The motors were driven using pulse width modulation (PWM) from a Parallax, Inc. BASIC Stamp 2e microcontroller. The BASIC Stamp also was used to sense the input from the bump sensors used for obstacle avoidance and from the passive infrared detector used to locate the heat signature of victims. The primary focus of our efforts was to show that sufficient coverage of the search area could be attained with low-cost (essentially disposable) robotic swarms, since that approach seems to make the most sense for searching a large disaster area in the minimum amount of time.

To achieve the area coverage, we used a simple wandering routine in the software for the Blue Swarm robots. Each robot was programmed to go forward for a random amount of time and then turn a random number of degrees in a random direction. The robots were not programmed to cooperate or to avoid anything other than obstacles. Using this simple control scheme, we were able to get some impressive coverage of the yellow competition arena, which was the only area we could operate in with the chassis' we were using. On the last run of the competition, we were able to get a robot into each room of the yellow arena for 100% coverage of the simulated disaster area.

Figure 1 shows one of the Blue Swarm robots in the yellow arena.



Figure 1. One of the Blue Swarm robots in the yellow arena of the Urban Search And Rescue course.

Problems

The biggest problem we had with the Blue Swarm was a lack of communication with the robots. The robots had no way to tell us where they were when they found a victim, so we had no way to display a map for the human rescuers to enter the building and find the victims. Communications between the robots could also have been useful as a way of getting the swarm to maximize the coverage area in the minimum amount of time. If the robots had been able to avoid each other, we wouldn't have had the problem of two robots operating in the same area, as frequently occurred during the contest. The robotic cooperation needed to do this would have been fairly simple to implement - we could have just used a light or a tone that the other robots would be programmed to avoid. This is a problem we will address in future competition entries. The problem of reporting location is a little more difficult.

We had been investigating two approaches to this problem. One was to provide each robot with the ability to determine its position, either through dead reckoning or with an aid like a GPS receiver. The problem with

this approach is that it increases the cost and complexity of the individual swarm robots. The other approach we investigated was to use an external mechanism to determine the location of a beacon set off by one of the swarm robots when it located a victim. This external mechanism could take one of a number of forms. We considered setting up receivers outside of the arena that could triangulate the location of the beacons or the use of another robot that would act as the coordinator for the swarm. The coordinator would remain in contact with the swarm robots and would be able to report the location of the swarm robot whose beacon has gone off. This approach has the advantage of putting the complexity into a smaller number of coordinator robots, but has the disadvantage of limitations on the span of control for the coordinator robots and the possibility of a single point of failure if something happens to one of the coordinators. We are actively investigating this approach for next year's competition.

Another problem we encountered was to accurately locate victims autonomously at low cost. We were trying to use the infrared signature of the human body for victim location, but there are a number of drawbacks to doing so. One is that the ambient heat (especially in a real disaster area, like the World Trade Center) can mask the heat signature of a person. Another drawback is finding other heat sources instead of victims, such as hot water heaters or fires. One way to avoid this problem is to use multiple sensors, like sound and motion sensors. This has the drawback of increasing the cost and complexity of the swarm robots and can be ineffective if the victim is immobilized, unconscious, or dead. Vision can be used to locate a visual cue that looks like a body, but this is very difficult in an actual disaster area since it is difficult to predict how much of a body will be visible or what shape it will be in. Vision is also very expensive in terms of computing costs. This multiple sensor approach is another area we are actively investigating for next year.

Future Work

We have formed a larger team for the 2002 USAR competition, so we hope to be able to take a more ambitious approach to finding solutions to some of the problems we had in the 2001 contest.

We have decided to use at least one coordinator robot to provide mapping of the disaster area and location of victims. The coordinator will be based on a Radio Shack *Sentinel* radio-controlled tank chassis. This chassis was selected because of its low cost and ability to handle moderately rough terrain. Current plans are for the coordinator to provide map inputs and a video feed to the rescuer's PC. It will use ultrasonic sensors to avoid obstacles and will communicate with the swarm robots in a

manner that has not yet been determined. The interface on the PC will consolidate the map inputs into a single map that the human operator will have the ability to mark with suspected positions of victims, cue areas for further investigation, and take manual control of the coordinator's steering. The PC interface will have the ability to switch between multiple coordinators and will also provide a remote observation/control capability via the Internet.

We also plan to change platforms for the swarm robots next year. We discovered that there is just too much variability in the motors of the *Red Fox* cars, so each robot has to be individually programmed to take account of the idiosyncrasies of its set of motors. And, by the time the parts were purchased and the circuit boards assembled, the modified *Red Fox* cars cost just as much as purchasing a *BOE-Bot* or a *GrowBot* from Parallax. We intend to purchase a swarm of these (more reliable) robotics kits for next year.

Conclusions

The robotics team at Utah State is convinced that a swarm of low-cost, simple robots is the best approach to solving the problem of Urban Search and Rescue. If the design were simple enough, the robots could be mass-produced (have you seen how sophisticated electronic toys are getting?) and shipped to disaster sites anywhere in the world. If the price were low enough, the robots wouldn't even need to be recovered afterwards. There are still a number of issues to be addressed before a USAR swarm could be made practical, not the least of which is getting human search and rescue teams comfortable with the idea of working in an area where robots are operating. This issue shouldn't be critical if the robots are kept small enough. This approach also doesn't need to be limited to USAR - it could also be applied to any area where robots are being used to look for something of interest, such as clearing minefields or exploring other planets.