

Blue Swarm Sentinel and Blue Swarm 2

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Abstract

This paper describes the Utah State University (USU) entry in the 2002 robotic Urban Search and Rescue (USAR) competition, hosted by the American Association for Artificial Intelligence (AAAI). More importantly, it also describes the problems the team encountered in preparing for this year's competition, the lessons learned, and plans for the 2003 USAR competition.

Description of the 2002 Entry

The USU entry for this year's USAR competition combined last year's entry (the Blue Swarm 2) with a coordinator robot (the Blue Swarm Sentinel). The concept was to have the Sentinel coordinate with the six robots making up the Blue Swarm 2 and relay pertinent information (especially the location of victims) back to a human rescuer viewing a PC-based graphical user interface (GUI) via a radio frequency (RF) transceiver. The team ran into some problems implementing this concept, as will be described in the problems encountered section of this paper. This section will describe the USU entry as it was intended to operate.

Blue Swarm 2

In 2001, USU entered the Blue Swarm 2 in the USAR competition, which was an improved version of USU's 2000 entry, the Blue Swarm. The Blue Swarm 2 consisted of six modified *Red Fox* remote control toy cars. The *Red Fox* was selected because of its low cost (under \$10 each) and its suitability for being made into a robot because it had independent motors for its drive wheels. In fact, this was the same type of toy car that Jonathan Connell had used for his well-known Omni Photovore. The USU team modified the *Red Fox* cars with a Parallax Basic Stamp BS2e for control and a dual Hbridge chip for driving the motors. The robots used bump sensors for obstacle avoidance and an IR detector for victim detection. Each robot was programmed with a slightly different random walk algorithm, so each robot would cover the area in the arena in a different manner. Because of the relatively simple sensors and drive train, the robots were limited to operating in the least challenging portion of the USAR arena. However, the biggest problem with the Blue Swarm 2 was that it didn't

have any way to communicate with rescuers outside of the arena. To solve this problem, the USU team decided to build a coordinator robot for the swarm: the Blue Swarm Sentinel.

Blue Swarm Sentinel

The Blue Swarm Sentinel was based on a Radio Shack radio-controlled toy tank called the *Sentinel*. The *Sentinel* had a couple of advantages that the team thought would make it a good chassis for the 2002 competition: like the *Red Fox*, it had two independent motors, which would make it easy to control with a microcontroller; it was fairly large, which would allow enough room for the sensors and RF transceiver; and, since Radio Shack was phasing it out, it was inexpensive (under \$20). Figure 1 shows a photograph of the Blue Swarm Sentinel robot.



Figure 1. The Blue Swarm Sentinel.

The Blue Swarm Sentinel was controlled by a network of three Parallax Basic Stamps. One stamp was responsible for controlling the motors and determining the position of the robot using odometry, the second stamp was responsible for interpreting all the sensor readings from the outside

world, and the third stamp was responsible for communications using the RF transceiver. The motors were driven by a dual Hbridge chip and the motion of each motor was measured by counting the number of times a contact switch with a roller closed as the tank tread passed under it. This wasn't the best possible method for measuring the motion of the treads, but it was the most cost effective and simplest. In addition to keeping track of the movement of the treads, a general heading could be determined from a 3-bit compass module. The Sentinel was surrounded by six infrared emitter/detector pairs: three looking forward, one looking to each side, and one looking backward. It also had an automotive-grade thermopile sensor looking forward to detect the heat signature from victims. There was a receiver and a transmitter inside the chassis that used two whip antennas to communicate with their matched pairs connected to the rescuer's PC (the black box in the photograph is the module that would attach to the serial port of the PC). The position of the turret on top of the Sentinel was controlled by a servo motor, which could turn the turret through a 180° arc from one side of the robot to the other. On top of the turret was mounted an X10 wireless color camera that provided an audio and video feed to the receiver connected to the USB port of the rescuer's PC. The block diagram for the Blue Swarm Sentinel is shown in figure 2.

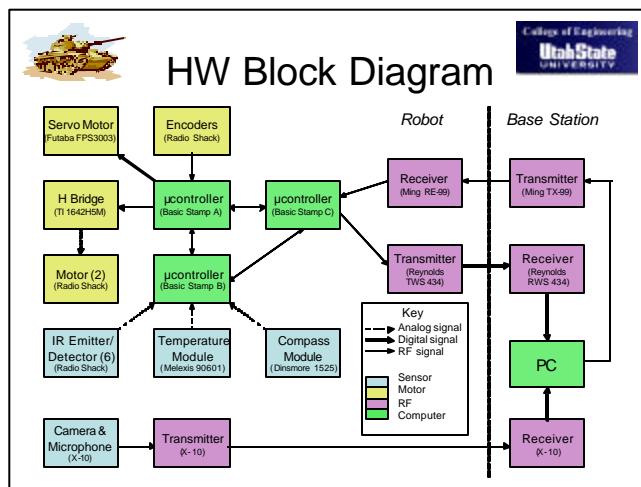


Figure 2. The block diagram for the Blue Swarm Sentinel.

The software for the Blue Swarm Sentinel had two modes: manual and autonomous. The human rescuer at the PC could switch between these modes by pressing a manual/auto button on the GUI. In manual mode, the human rescuer could steer the robot by pressing one of eight direction buttons on the GUI. The robot would then move one unit (about one foot when going forward or 1.414 feet when moving on a diagonal) and wait for the next button press. The rescuer would use the video feed from the robot to steer to a doorway to enter. The rescuer also had control over the turret in either mode (manual or automatic) and could pan the turret (and the camera view

along with it) either left, right, or back to the forward-facing home position. The intent was also to have the Blue Swarm robots follow the Blue Swarm Sentinel when it was in manual mode through the use of a beacon on the Sentinel. Once the rescuer had found an area he wanted the swarm to explore, he could put the robot into autonomous mode. At that point, the Blue Swarm Sentinel would attempt to seek out heat sources in the environment. It would also look for beacons from the swarm robots indicating that they had found a victim. In either case, the Sentinel would report the location of a victim to the GUI to be plotted on the grid-based map the GUI was building while the Sentinel was exploring. The locations of obstacles would also be reported and plotted on the map, along with the current position of the Sentinel. (The positions of the Blue Swarm 2 robots were not plotted by the GUI.) Figure 3 below shows the GUI used by the human rescuer.

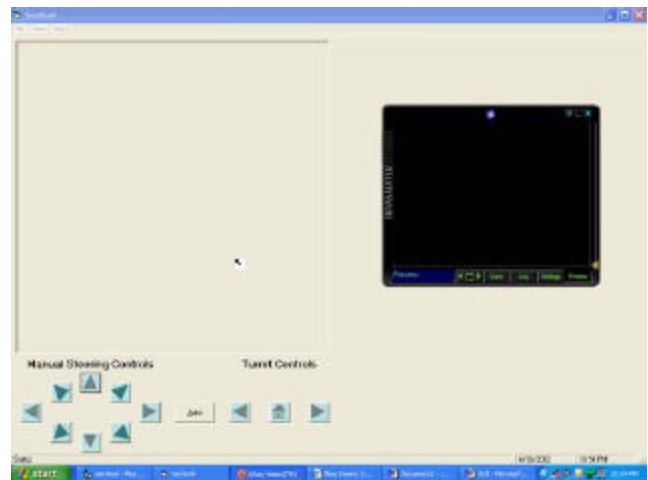


Figure 3. The human rescuer GUI for the Blue Swarm Sentinel. The window to the left is the map, with the arrow indicating the position and heading of the Sentinel. The manual steering controls, manual/auto button, and turret controls are all below the map. The window on the right is the feed from the X10 camera.

Problems Encountered

The USU team had a number of problems, both in getting the Blue Swarm Sentinel to work properly and in getting the coordination with the Blue Swarm 2 to work. In fact, the team encountered enough problems with the Sentinel development that the swarm interface was never completed before the competition. One of the big problems with the development of the Sentinel was trying to get the three Basic Stamps to talk to each other. The approach taken was to use the Basic Stamp's capability to perform serial communications with any of the 16 input/output pins on the Stamp to set up a ring network between the three stamps with handshaking provided by signals on additional I/O pins. Simple tokens and keywords were developed to

simplify the communications and to keep the time transmitting serially to a minimum. Even so, it was not uncommon to lose a message between the Stamps. An even more difficult problem was the RF communications. The RF modules required a number of unexpected software kludges, like needing to send dummy messages to wake up the transmitters prior to sending a real message. In addition, there were problems on the PC side, where the circuit the team had built to interface with the PC had to be replaced when it was unable to communicate with the serial port on the PC. The RF system also proved to be unreliable, failing prior to the competition. The RF system wasn't the only system to prove unreliable, however. The sensors also had problems with reliability—especially the compass sensor. The compass sensor had two problems actually. One was that the 3-bit module that the team had been forced to use because of the lack of an analog-to-digital (A/D) converter on the Basic Stamp didn't have sufficient angular resolution to be able to use it to accurately turn the robot. Because the compass could only determine the robot's heading to somewhere within a 45° arc, it couldn't possibly be relied on for anything other than a rough indication of which of the eight discrete headings the robot was currently on. The more critical problem was the compass' sensitivity to steel and iron in the environment. It proved to be unusable in most indoor settings, since the indicated heading would tend to align with structural elements in the building, regardless of the actual heading of the robot. This problem would manifest itself during the competition, along with extreme range limitations on the RF transceivers that were selected to replace the failed RF components.

Because of the problems encountered just prior to the competition, the only viable solution appeared to be to put together a simpler prototype to try to run in the USAR competition. A second *Sentinel* tank was converted for the contest, using two Basic Stamps mounted on Parallax Board of Education (BOE) prototyping boards. A simple serial link was set up between the two boards. One of the BOE boards was responsible for communications via a Parallax RF transceiver module, while the second BOE was used to control the motors and read the inputs from a significantly smaller suite of sensors. The sensors were a forward-looking ultrasonic pair for obstacle detection, a thermopile for victim detection, and a Parallax compass module for heading determination. Distance traveled was determined solely by dead reckoning. The camera and the turret were also abandoned for this robot since the BOE boards didn't leave enough room to mount the top shell on the chassis. While the robot was able to enter a portion of the arena and was able to detect victims, due to the heavy steel beams in the roof of the convention center the range of the RF transceivers was too limited to reach the "safe area" the human rescuers were required to work in. As mentioned above, the compass module also failed to give valid direction readings inside the convention center. Figure 4 is

a block diagram of the prototype robot used in the competition.

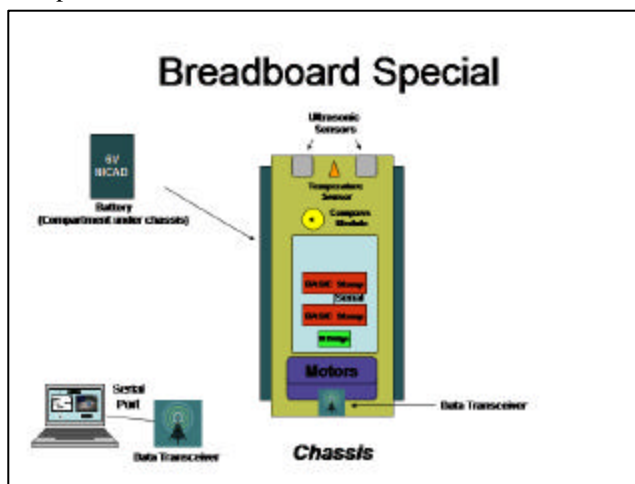


Figure 4. A block diagram of the prototype robot entered by the USU team in the 2002 USAR competition.

Lessons Learned and Future Work

It is apparent now that the Blue Swarm Sentinel was too complicated to operate reliably in the USAR environment. It also relied on sensors (like the compass) and communications systems (RF transceivers) that proved unreliable even inside a standing structure—they certainly wouldn't be reliable inside a collapsed structure. Additionally, greater redundancy within the swarm is needed so the failure of one robot doesn't incapacitate all of them.

As a result of these lessons learned, the USU entry in next year's USAR competition will be based on a larger number of simpler robots using line of sight communications with at least two different communications channels to ensure the map can get out of the USAR arena to the human rescuer. The underlying idea is to take the first steps toward a truly portable, disposable swarm that can be quickly deployed at a disaster site and give first responders a rough idea of where they should focus their rescue efforts. While next year's entry will probably be a subset of the swarm that would be necessary to provide coverage of the entire arena, it should serve to validate the viability of this new approach.

References

Connell, J. "The Omni Photovore: How to Build a Robot that Thinks like a Roach", *Omni Magazine*. October 1988, pp. 201-212.