

CPSC 483 Senior Design Project Proposal

Wireless Networks for Multi-Robot Communications

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Purpose

We request funds and advising from professor and teaching assistants in order to develop a wireless communication network for multi-robot teams. This network will allow the robots to function as a sensor array, in order to function to a singular purpose: the finding of an object. Specifically, the robots will communicate using radio frequency, or RF.

Background

Many projects that involve the use of robots involve more than one robot. In order to do a job, these robots must work in parallel. The need for these robots to be able to communicate with each other has led to the development of sensor networks.

A sensor is a device that produces a measurable response to a change in a physical condition. A sensor network is a series of robots that contain sensors, and use the results from these sensors, and communication with each other, to achieve some shared goal.

Many times sensor networks are distributed, meaning that all of the robots share duties. Many network communication are on a client server setup, where one side gives

directives to another. A distributed is communication among equals. There is no one single error that can take down the system. Any single unit can be disabled, but the network itself will continue to function.

Many applications benefit from such sensor networks. A network of robots can cover a large area, with each robot going in a different direction. A faster solution can be found if more than one path is taken at the same time, as with a sensor network. A groups of robots is also less prone to total failure, for if one robot breaks down, the rest can still complete the objective. This makes sensor networks ideal for search and retrieval missions, where their large coverage and constant communications mimic that of a human search party.

There are also some problems with sensor networks. The largest hurdle is the requirement to be able to constantly communicate with other, while mobile. This makes both line of site transmission systems, like infrared, and wire based solutions unfeasible. This communication must also be set up on the fly, as machines should able to enter and exit the communication process at any time.

The robots must also be cognizant of the other robots, and at least their relative position to it, in order to be able to effectively share information about their surroundings. It is not enough to know that x robot has found the objective. In order to use this information, it must know the location of the other robot.

Communication itself poses some challenges. If the robots are not in close contact with each other, messages must be passed from one robot to another in order to route them to a specific robot. When we add to this the fact that any one node can fail at any time, this leads to problems.

Problem Statement

Develop a wireless communication network for multi-robot teams. This network, preferably made with radio frequency transceivers, plus the on board sensors of the robots themselves, will form a sensor network, in order to locate a light source.

This will require the following:

1. A wireless communication system for multiple small robot micro controllers.
2. Schematic diagrams, parts list and instructions to assemble the system.
3. Project documentation, as described in the course syllabus.
4. A live demonstration of the robot in action.

The system is the main part of the project. It includes the robots, network protocols, and software running the robot. This should all be in both written form and on the robots themselves.

The schematics and instructions should be clear enough so that anyone who wanted to recreate the project could so easily. It is meant as a

The documentation should cover the process of building the robot, as well as evaluations on process and management style. It should include a copy of this proposal, a user's manual for operating the robots, and comments on the success or failure of the project.

The demonstration will be done at the end of the project, and will show the robots in action. This should be somewhat visual, as people outside the class will be observing it.

Design Constraints

The “wireless networks for multi-robot communications” project consists of requirements or goals that either must be or should be followed. Constraints that must be strictly adhered to are listed under the “must” category. Conditions that should be at least considered but are not deemed critical to the application of the project are listed in the “should’s”.

This project must:

- Maneuver around obstacles. When an obstacle is encountered, the robot should take action to avoid a dead stop. Solutions include but are not limited to infrared sensors, feeling whiskers, object recognizing cameras, and ultrasonic radar.
- Be able to navigate independently of other robots. Each robot must have the ability to search independently of the others. Also, it must have some sort of navigational protocol such as random pattern, expanding circle, or straight lines until a barrier is encountered.
- Search for a user specified target such as a light. Each robot has to be able to search for and find some predetermined target.

- Realize when it has found item or other robot. The robots must know when it is close enough to the target or, if searching for a light, must determine when the brightness of the light is satisfactory.
- Signal the other robots when the target is found. The discovering robot should send out a broadcast that it discovered the target.
- Search for the robot that signals it has found the target. At that point it must supply some sort of tracking mechanism for the other robots to find its current location.
- Not all communicate simultaneously. A protocol must be developed which will allow the robots to listen prior to broadcasting. When the airwaves are clear, the robot may speak. If multiple robot attempt to speak at exactly the same time, the robots can wait for a random amount of time and attempt to rebroadcast.
- Not interfere or be interfered with in terms of RF communications. Surrounding wireless networks, telephones, and other electronic devices must be considered when choosing the frequency of the RF transceivers.

This project should:

- Allow the designers to easily modify the system behavior. Because of the complexity involved with communicating among multiple nodes, the designer should not get bogged down in the detail of how to write to and modify a chip.

- Allow the designers to easily interface new sensor and communication devices. Because the obvious need for additional sensors (possibly transceivers, cameras, ultrasonic sensors, infrared, whiskers), designers should have ample I/O connections and ease of interfacing.
- Use parts and tools readily available. Because of the numbers of robots needed, the other various parts should be “off the shelf” parts if possible. Also, when choosing parts and robots, the tools needed should be considered.
- Sense obstacles to avoid contact. This could possibly allow the robots to save power by preventing them from sporadically changing directions upon contact with an obstacle.
- Consist of robots that will move reliably on the specified surface. The robot wheels should be able to cope with the environment. Likely, a low pile carpet or tile floor will be used. Consideration must be made for traction on tile.
- Allow for close enough distances so that the RF communications will not fail. If by chance the RF communication link is extended beyond its usable distance, a search and rescue protocol should be considered.

Metrics

The following metrics can be used in order to determine the validity of various solutions to the networking robots problem.

1. Cost

The robots used in the project must be available for a minimum of cost. Sensor networks usually cover tens or hundred of identical robots, each doing a small task. While our goal is not that lofty, in order to develop a sensor network, we will have to have at least 3 or more robots, each with identical capabilities. This will make minimizing the cost of each of the robots in the project a high priority of the project.

2. Stability

One of the greatest properties of a sensor network is how functions and data are distributed over the network. Each robot only does a small part of the job, and combined, they do the task. Any sensor network we design must have the ability to function whether or not all units are functional.

3. Size

In order to effectively design a sensor network project that can effectively exercise the sensor network's capabilities, one of two goals must be met. Either the area we test the sensor networks must be large enough to require multiple robots to cover the area, or the robots must be small enough in respect to the area of coverage. As making robots that will cover a large area will probably be cost prohibitive, the robots that are in our project should be small enough to make a small area an effective test.

5. Adaptability

In order to do the various tasks of this project, whatever robot we use will have to be able to use a variety of different inputs and outputs. More may be added, if we wish to expand the nature of the program on a later date. One metric for any robot we use will be the ability to add on different sensors and transmitters.

These items will allow the robot to both communicate with other robots, and search its surroundings, both parts of the sensor network. The ability to add expand with additional inputs and outputs might also be beneficial when debugging, where various events could cause the robot to light a light or ring a bell, in order to show what was happening.

Work in this Field

Currently, there are several projects that have concentrated on sensor networks at various universities and government agencies. Some of these have reached a prototype stage.

One of the most notable is the **DARPA** (Defense Advanced Research Projects Agency) project for sensor networks. They envision “smart dust”: a sensor network made up of thousands of tiny robots, each communicating with each other, and relaying information about the battlefield. The objective is to make the robots small and light enough to float in the wind, scattering them, and landing on all surfaces.

Part of the **DARPA** project uses an open source operating system and database known as TinyOS and TinyDB, respectively. This operating system is a runtime environment designed embedded systems which require concurrency operations while constrained by minimal hardware resources. Many different universities are using this as a starting point for their own projects.

One of the largest examples of using TinyOS was a Habitat monitoring project on Great Duck Island. Thirty-two units, or “motes”, were deployed in order to monitor environmental conditions on the island. Each could display temperature, humidity, and other environmental data.

Another example using TinyOS was to connect a building with a hundred motes in various places. These monitored temperature, electric and light conditions. They collated this data for the user, showing what parts of the house used electricity. This allowed for more informed energy consumption.

Sensor networks could also have many non-military applications. One idea is that of “pervasive computing”. This is where thousands of small computers are inside you, and on your body, forming a “nervous system” of sorts, that gathers and collates data. It would allow different computers to “recognize” you based on the computers on your body.

One small step in this direction is RFID tags. Radio Frequency Identification tags are tiny microchips that respond to radio frequencies with a transmission of their own. They are currently being tested in many consumer goods, where the ability to identify individual goods quickly. Currently, each tag transmits a 64 bit response to a radio signal, so they can have 18 thousand trillion different values.

One topic in computer science that predates the field of sensor networks is artificial life. Unlike artificial intelligence, which tries to simulate a human mind, artificial life uses animal like behaviors in order to achieve some goal. It uses small rule sets to produce complex behaviors. Each artificial life “creature” only knows about its general area and makes decisions from what it can see. Several computer simulations have had artificial

life creatures simulate flocks of birds, and other pack animals. Some of these are self evolving, changing their programs while running in order to produce better results.

Some less advanced sensor networks are used in factories. While traditionally networked, and with much larger sized sensors, they still are effective. An example of this is the sensors in an automobile, that record pressure and temperature values. These sensors are not mobile, but have some intelligence and communication capabilities. They also report information back to a source.

Survey of possible robots

When considering what robot to purchase to start on our project, our team had several concerns. The top priority was to find a robot that was somewhere in the two hundred to four hundred dollar range. Our problem statement asks for a multi-robot team that is able to communicate with each other. We decided on purchasing five robots with the possibility of adding an additional five later on. To stay within a reasonable budget, we had to keep the price of each robot down.

We took the five most promising robots and critiqued each. The first robot we looked at was the AmigoBot by ActiveMedia. The AmigoBot comes with the standard physical characteristics and capabilities. It is 28 cm long (~11 inches) and 33 cm wide (~13 inches). It comes with 1 MB of flash memory and an indoor range of 100m and an outdoor range of 250m. ActiveMedia also comes with wireless accessories like the Wirefree Radio Modem. This option would be very useful in our case since it is full duplex and uses the standard RS232 serial port. The downfall of the AmigoBot is that it uses its own operating system, AmigoOS and the price is currently at \$1795 each.

The second robot we took into consideration is the Khepera II by K-Team. K-team's product came with more memory than the AmigoBot but less Flash memory. K-team fell short of our expectations in several areas. The sensing whiskers that ship with the robot are only 10cm long. The payload for the robot is only 250 grams and the RF products might stretch that limitation. The Khepera model also comes with software that is not made specifically for its product. It ships with National Instrument's LabView and MatLab. The unit price of the Khepera is not listed on the website and the only way to figure out the price is to send off an email and wait for a reply back.

The next robot we looked into was the Trilobot by Arrick Electronics. This robot measured 12" x 12" x 12" and weighed 11 pounds. The Trilobot is the heaviest of the

robots that we took into consideration. It also requires the most voltage at 12V. The main disadvantage of the Trilobot is the price. Each product is \$1900.00 which is out of our price range.

The fourth robot on our list was the Hexapod by Lynxmotion. The Hexapod has the simplest and straightforward design. We found the documentation to be very lacking though, and we were not ready to gamble on whether the product would fit our needs or not. The Hexapod costs around \$240. The payload is also only 12 ounces, which again might not be enough to handle the additional RF Products.

The final robot that we surveyed was the Boebot by Parallax. It turned out to be the best candidate for our project. It sells for around \$230 a piece and comes with two helpful workbooks. Boebot comes with whiskers and is constructed of an aluminum chassis. The Boebot has a smaller, yet strong frame so we will not need a large testing area.

Design Validation

Each piece of the Boe-Bot can be tested individually and then tested again when everything is put together. The servos, whiskers, photoresisters, and IR subsystem can each be tested individually as outlined in the Boe-Bot manual. Then we must test the servos, whiskers, photoresisters, and IR subsystem when all of them are working in unison. We need to implement and test a random search for light using a single Boe-Bot. Then we need to implement and test patterned searches for the light using a single Boe-Bot.

At the same time we can begin implementing and testing RF communication between two Boe-Bots. Following successful communication between two Boe-Bots, we can develop, implement, and test a communication protocol for an arbitrary number of Boe-Bots.

Upon successful implementation of a multi-Boe-Bot communication protocol and the individual Boe-Bot random and patter searches, we can combine the searches with the communication protocol to implement multi-Boe-Bot random and pattern searches for light. This step will require an iterative series of test as we determine which search is best, how close the Boe-Bots should get to each other before changing direction, and try to develop a method for each Boe-Bot to determine where the other Boe-Bots are at all times. We will then need to test this with various obstacles blocking the search for the light and with removal and addition of Boe-Bots to the search.

Societal, Environment, and Safety Analysis

Use of small autonomous robots for different tasks stands to have great benefits for society. They will allow for jobs to be done cheaply by many small robots instead of expensively by large ones. Sensor networks will allow people the ability to monitor events over very large areas with ease.

There are some problems with sensor network technology. If sensor networks are so ubiquitous, it might be very easy to have millions of them, monitoring everything in a given area. The privacy concerns are significant. This should be minimal for our project, as it does not concern robots in any large number. Neither do the Boe-Bots have any capacity for surveillance work.

The use of large amounts of Boe-Bots would have some environmental concerns. As the Boe-Bots are small, and easily damaged, many might have to be thrown away. The electronic chips and plastic that are used to create a Boe-Bot are not biodegradable and the chips may contain hazardous materials.

Using five Boe-Bots may also cause other problems. Each robot requires four double A batteries. Depending on how often these need changing, they might generate a large amount of somewhat hazardous waste. Batteries become corrosive with time, so proper disposal of the batteries is necessary.

Using a Boe-Bot may have some advantages environmentally though. Five Boe-Bots may be able to do the job of one larger robot. This robot could use more resources than the smaller robots, and must be replaced if broken. Each of them also probably uses much less power than the larger robot, and probably costs less.

Safety concerns are minimal for the BoeBot. They are quite small, and there is little chance that any collision with a human or any other object will result in any damage. The amount of power they consume is quite small, so any exposure to an open circuit will result in only a small electric charge. The only real hazard the robot poses is the threat of when it breaks. If the robot is broken into small pieces, there is a chance that they could be sharp and cut something or someone.

While the BoeBot poses little threat to outside elements, these elements may pose threats to it. It might be easily stepped on, causing large amounts of damage to the robot. It could also be exposed to the water, or other elements, also causing damage to it.

Feasibility Study

Project Schedule – 13 weeks

Team Meeting – 1/27/03

Start Date – 1/27/03

End Date – 5/5/03

*note: See Gantt chart for schedule details

Project Deliverables

Bi-weekly Report – 2/17/03

Critical Design Review – 3/3/03

Bi-weekly Report – 3/26/03

Bi-weekly Report – 4/09/03

Bi-weekly Report – 4/23/03

Final Report and Demo – 5/5/03

Objectives/Statement of Work

The objective of this study is to show that the proposed sensor network system is physically, technically, and economically feasible in the time available. According to the initial budget plans, projects are limited to \$1000. Because of the number of robots needed to implement the minimal size of the network, this number is flexible. The calculated budget of a little over a thousand is within reason.

Most of the technologies that are being implemented come with the robot. The whiskers, infrared, and photocells have all been tested and used with Boe-Bots for various applications and can be easily added with the serial interface. In the communication aspect, we are using a mature RF technology. Many sample programs are available as guidelines. Work has been done at several universities with wireless sensing networks.

As seen in the Gant chart , we should have enough time to complete all design objectives. We should also have some room for unexpected problems if any occur. The mistakes may come from trying to integrate all of the different parts of the robot into a whole, but there should be enough time to do this.

Management

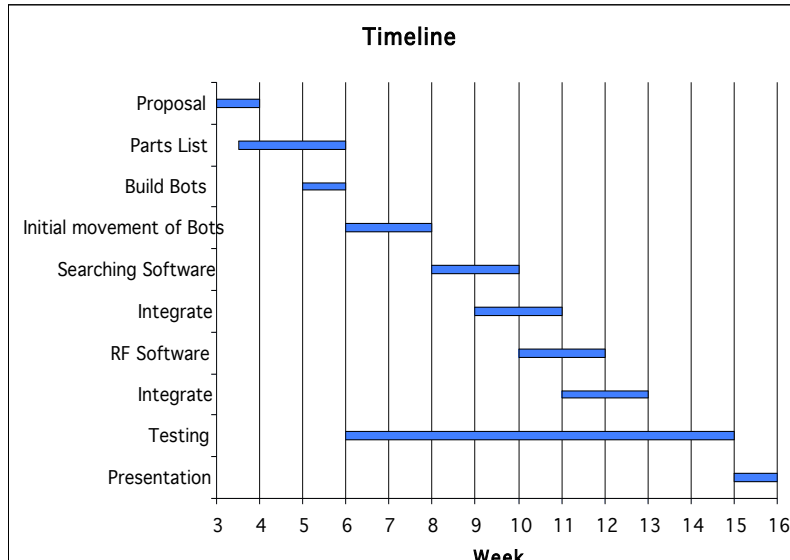
Team organization will be loosely based. Decisions will be made by group consensus, and then carried out. Tasks will be delegated based on who can do the job effectively and quickly.

If there are design disagreements, we will either ask the profession for advising, or see if some form of compromise can be made.

The project will be managed under a cycle type of qualifications. Each unit will be planned, designed, and tested. Then, all units will be integrated, then the whole will be tested.

Scheduling

Our timetable looks like the following:



As shown, there is plenty of time for both design and testing of different components in the system, as well as testing of these various components. Each unit of the project has been checked for dependencies with all of the others.

Most of our work units will take two weeks. There is some leeway in the testing, as it is an on going, continuous process. It will be done as units are completed. The presentation itself will be done after the software and hardware is finished.

There are several dependencies for various subunits of the process. The robots must be built before any of the other work can be done. The IR, RF, whiskers, and photocells are all independent of each other. In order to search for a light, the photocells, whiskers, and

IR must be completed. Robots talking with each other require the RF to be completed.

Finally, both are required for the fully functional robot to be built.

Budget

Our Budget will look like the following:

Sensor Networks Budget

Product	Quantity	Price
Boe-Bot Full Kit	5	1145
w/shipping		1157.28
Transmitter (TWS-434)	5	38.25
Receiver (RWS-434)	5	38.25
433 MHz Antenna	5	45
w/shipping		130.84
Alkaline Batteries (AA)		100
Total Cost		1388.12

The total cost goes come to slightly above 13 hundred dollars, a reasonable amount for our project.

