9/21/2012
CPEG498-499
Dr. Cotton

Collaborative Robotic Mapping
Team SKYNET

Team Members

[redacted]

Objective

The objective of this project is to design and build a team of four robots which will perform collaborative indoor 2D mapping. The robots will perform limited inter-communication, but will communicate all of their data readings to a passive receiving computer. This computer will analyze and combine the data to create a single 2D map.

In the event that we fall short of multi-robot collaboration, partial project success might involve a single mobile robot communicating with stationary position markers (see section on division of labor and fall goals). Another version of partial success could be multiple robots mapping independently (no collaborative position tracking), with the maps still being combined by the central computer. Failure will be defined as anything short of the above.

Customer

This project could have future applications in mapping hazardous areas. For example, future versions of our robots could be used to map a building prior to entry by soldiers, or to explore an abandoned mine. The project could also be applied to search and rescue in similar situations. Our current project will be a prototype for field designs, to test the communication protocol and positioning algorithms. More durable and maneuverable robots will need to be designed for field applications, but a success in this project will set the groundwork.

Constraints on the Design

The two main constraints on our robots will be cost and complexity. Our design for each individual robot must be as cheap as possible since we are planning on making four nearly identical robots. With that, the robots must also be as simple as possible to minimize swarm construction time and to reduce the total project cost.

Approach

In our current approach, three robots act as stationary position beacons while the fourth robot explores the territory. The roaming bot can request a distance measurement from each beacon bot, and can use these distances to trilaterate its own position. After ascertaining its position, the roaming robot will use distance sensors to detect nearby walls and objects. This information will be communicated to a central computer, which will consolidate all the points into a common map. When the roaming robot gets too far from the beacon bots, it will broadcast a signal that it is becoming a beacon, and one of the beacon bots will take over as the roaming bot. In this manner the robots can move together through the target building's halls.

The work for this project can be broken down into several categories:

- Making the robots work (mechanically)
    - A significant amount of work with go into testing the motors, building the motor controllers, using arduinos to control the motors and get the robots to drive, turn, stop, etc. in a controlled fashion.
- Distance sensing between robots
    - Proposed method: When the roaming robot wants a position reading, it will turn on an infrared (IR) LED and at the same moment emit an ultrasonic chirp. The beacon robots, sensing the IR LED, will immediately begin a countdown. They will stop the countdown when they receive the chirp and calculate the distance based on time elapsed and the speed of sound.
- Wireless communication
    - We need to investigate different types of wireless communication (bluetooth, Xbee, etc.), and choose wireless modules that can interface with arduinos. We then need to set up communication between the robots and the central computer.
- Central map creation
    - We will need to design mapping software (to be run on the central computer) that can combine the data from multiple robots into a coherent map.

Division of Labor and Fall Goals

Since this project has a number of complicated aspects, our first goal is to isolate the different functions and refine their operation before combining them into a single functional unit. The first task that we are going to focus on is the location determination techniques. This will test the robot's ability to determine its own location based on the location of another device. The systems tested by this are the ultrasound distance measurement and the inter-platform communications. The setup will involve several immobile platforms with the anticipated sensor builds of the robots. One of these platforms will be set in 'explore' mode while the others will be in 'beacon' mode which know their positions. The exploring robot will be manually moved and then scan for the distance change and calculate its new location relative to the stationary platforms.

The other task which would need to be completed is controlling the robot's motion and determining when and where the robots should move. Eventually after finishing single robot motion, the process could be upscaled to incorporate multiple moving platforms. Location determination and single-robot motion are ambitious fall goals for our group, and are contingent upon the success of our more manageable individual goals:

- [redacted]
    - Responsible for: Software to be run on the central computer

    - Fall goal: Write a python program that can receive bluetooth data from multiple sources and translate that data into a central map
- [redacted]
    - Responsible for: Software to be run on the arduinos attached to each robot
    - Fall goal: Create a working program that can read data from sensors, send data over bluetooth, and control robot motors
- [redacted]
    - Responsible for: Wireless communication (bluetooth)
    - Fall goal: Set up a communication network connecting the robots to one another and to the central computer
- [redacted]
    - Responsible for: Distance sensing between robots
    - Fall goal: Test the accuracy and feasibility of our proposed method of infrared / ultrasonic distance determination
- [redacted]
    - Responsible for: Robot hardware (primarily sensors)
    - Fall goal: Test range, accuracy, and usability of various sensors (range finders, compasses, bump sensors, etc.)
- [redacted]
    - Responsible for: Robot hardware (primarily motors, power, etc.)
    - Fall goal: Test and characterize the motors (voltage, current, RPM, etc.), help with the design of a motor-driver board

Equipment Needed

- Car bases - four or two axle (x4)
- Sonar transducers - 2 per car (x8)
- H Bridge circuitry for motor controls (x4 - x8)
- Microcontroller (Arduino) (x4)
- Wireless communication modules (x4)
- Radio or IR communication module for pre-sonar notification (x4)
- Laptop for data collection and robot monitoring (x1)
- Electronic compasses? Orientation detection (x4)
- IR sensor for wall detection (x4)
- Servo for IR sensor rotation (x4)

Budget Estimate

$199.99

Tentative Schedule

Fall Semester

Date	Tasks
9/18/12	• Finish project proposal • Define a weekly meeting time and place • Create team website

9/25/12	• Make list of needed parts • Create hardware and software block diagrams • Begin testing ultrasonic sensors • Start design of server mapping software
10/2/12	• Finalize parts list • Construct robot chassis • Test and characterize motors • Begin testing bluetooth modules
10/9/12	• Preliminary parts order • Begin designing PCB prototypes • Begin writing arduino robot-control software
10/16/12	• Establish bluetooth communication between arduinos and server
10/23/12	• Finalize design of prototype circuitry • Complete PCB prototypes • Set up arduino control of motors/motion
10/30/12	• Order PCB prototypes • Order parts for PCB prototypes
11/6/12	**Election Day - No class**
11/13/12	• Complete soldering of PCB prototypes
11/20/12	• Complete testing of PCB prototypes / making modifications (if necessary) • Complete construction of prototype robot • Begin creating Fall final presentation
11/27/12	• Complete initial testing of prototype robot
12/4/12	**Fall Final Presentation / Demo**
12/11/12	**Finals Week - No class**

Spring Semester

Week	**Tasks**
2/5/13	• Revise project proposal to reflect current project progress • Begin writing second semester parts list
2/12/13	• Construct 3 additional robot chassis • Begin updating PCB designs
2/19/13	• Improve/refine robot-control software • Add averaging/outlier rejection to mapping software
2/26/13	• Work on coordinated motion algorithms
3/5/13	• Finalize final PCB designs • Finalize second semester parts list • Begin work on mid-term report and presentation
3/12/13	• Order final PCB designs • Submit second semester parts list order • Complete mid-term report and presentation

3/19/13	**Mid-term status report and presentation**
3/26/13	**Spring break - No class**
4/2/13	● Complete soldering of final PCBs
4/9/13	● Finish construction of all robots
4/16/13	● Debug robots!
4/23/13	● Debug robots!
4/30/13	● Begin work on final report and presentation
5/7/13	● Champagne and celebratory mapping demo
5/14/13	**Spring Final Presentation / Demo**

Challenges

I. Wireless communication:

(a) The difficulty of inter-robot communication will pose challenges to our group. For example, there may be collisions as robots try to broadcast communication signals. It will also be difficult to minimize the error in distance calculation between robots. Because robot-to-computer communication will require a different channel anyway, we can move non-time-sensitive robot-to-robot data communication to that channel. That channel will likely use an out-of-the-box method, leaving us time to focus on inter-robot signals.

(b) There is also an optional networking problem, implementing incremental updates of the computer map. For now, we will assume that the data processing occurs all at once, once all data has been received.

II. Signal Processing:

Having multiple sensors tuned to the same frequency range will pose difficulties, especially when attempting to distinguish from which direction a chirp originated. We will need to experiment with our sensors to learn how best to control them.

III. Movement:

(a) Keeping the robots moving together down a hallway or through a room will be difficult. Theoretically, it will be possible with four robots to keep consistent position information by moving only one robot at a time, using the other robots to track its distance, and then updating its position. In practice, because of layers of measurement errors, this may not be effective. It may be a struggle to calibrate the bots to be able to harvest useful data in this manner.

(b) The question of orientation will be difficult to address because compasses will behave poorly around electronics.

(c) It will be difficult to program the robots to explore for new territory. Individual robots do not keep working copies of the map. Once they reach the end of a hallway, it will be difficult for them to (i) retrace their steps back to an unfamiliar area and (ii) do so without accumulating massive positioning errors.

References

- Sonar Transducer: http://www.allelectronics.com/make-a-store/item/XDR-24/ULTRASONIC-TRANSDUCER/1.html
- Two wheel robot chassis: https://www.sparkfun.com/products/10825
- IR long range sensor: https://www.sparkfun.com/products/8958
- H-Bridge: https://www.sparkfun.com/products/315