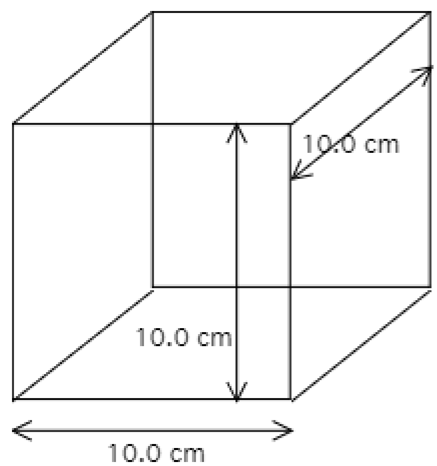
Lab 5: Searching for Objects

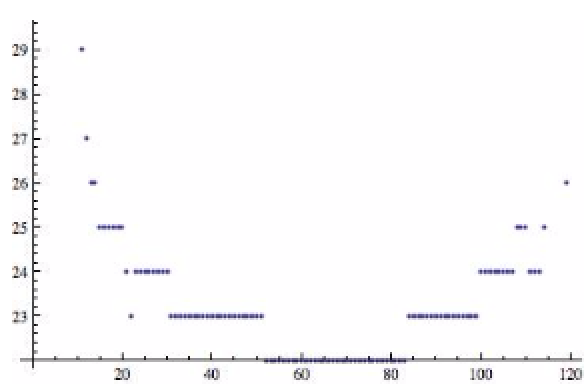
Background

This semester's project relies on both players being able to search for a specific object within an enclosed area using the sensors available in the Mindstorms kit. Objects can be differentiated in many ways, with texture and shape being the primary features used to distinguish them. In this experiment you will use the light sensor (which returns RGB color intensity as well as the color detected), and ultrasonic sensor (which can be used to measure shape). In both cases the sensors need to be scanned in order to integrate information from different parts of the surface being viewed.

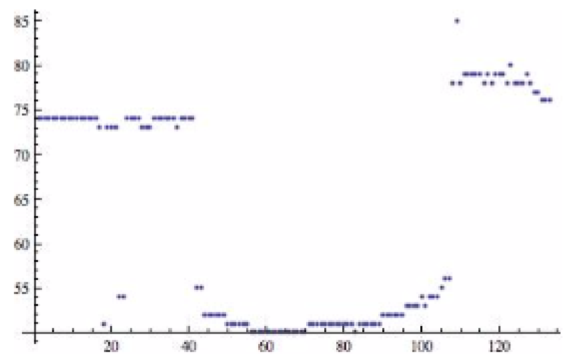


Shape Using Ultrasonic Sensor

The ultrasonic sensor supplied with the kits returns the distance to the closest surface within an approximately 30° field of view, so to determine shape the sensor must be moved or scanned. Consider the Styrofoam block shown above. If the ultrasonic sensor is positioned so that it is parallel to the ground at a height of 5 cm, and swept by rotating from left to right (like a radar antenna), the following profile is obtained (below).



In the next example, instead of rotating the sensor we translate it parallel to the face of the block resulting in the profile shown above. Here the sensor is approximately 50 cm away from the block. Notice that the most prominent features are the two locations where the change in depth is large (C^0 or depth discontinuities). What is convenient about these features is that they are easy to detect using the difference method we used earlier to find gridlines. We can take this one step further by putting units on the X-axis by noting the change in position of the robot as it translates the ultrasonic sensor, giving us the dimensions of the block face. In the above example, we can identify the block by comparing the dimensions of the block face against the Styrofoam block models. This can be sufficient to differentiate the Styrofoam block from the 3 different wooden block models that we have in the lab.



Using Color

The second example above is somewhat misleading as ultrasonic sensor measurements do not always give such unambiguous profiles (you probably already know this from the previous lab experiments). Since the Styrofoam blocks are known to be different in color from other objects in the scene, using both color and shape information would seem to be a more reliable strategy. The color sensor in the Mindstorms kit can return both RGB (red, green, blue) values and an integer specifying one of an enumerated list of colors. As mentioned in class, determining color is a difficult problem as it depends not only on the surface properties, but also on the color of the illumination. What appears as a 'blue' in noon daylight might appear closer to black in the late afternoon.

One approach to this problem is to observe sensor response to colors under different illuminant conditions. For example, one might collect samples from the surfaces of different Styrofoam blocks in different lighting situations (e.g. in the lab, in the Trottier Lobby, etc.). These could be in the form of distributions of RGB values or more simply the color codes returned by the "color ID" mode. In more advanced courses you can learn how to use these data to build decision models, also known as machine learning. For now, it might suffice to determine ranges for each color component (or color label), and to label an unknown measurement as corresponding to the color of a Styrofoam block of the RGB or color values fall into an admissible range.

With this albeit simple background on shape and color we can proceed to some laboratory experiments.

Instructions

1. Object Detection

Write a Lejos program that uses the light and/or ultrasonic sensor to detect one of the Blue Styrofoam blocks from the lab. You are free to design the program in any way you want, but it must be able to do the following – when an object is brought in proximity to your sensor(s), the LCD must display “Object Detected”. If the object is a Styrofoam block, the next line in the display should read “Block” or “Not Block” otherwise. You should be able to demonstrate 5 successive trials to the TA using a Styrofoam block and one of the wooden blocks in the lab.

2. Searching for Objects

Next, modify your robot as necessary to perform the following sequence of operations as part of a single program. Your robot will be placed in the lower left hand corner of the floor and started by a button press. From this point on your robot must be fully autonomous in performing the following operations:

- Localization: Your robot starts by localizing to the (0,0) coordinates of the grid as in Lab 4.
- Search: Your robot then uses its sensors to search for objects on the floor. When it encounters an object it should beep once if the object is the Styrofoam block and twice otherwise. If the object is not the Styrofoam block, it should move away from the object and continue searching.
- Capture: If a Styrofoam block is detected, your robot should push it to the upper right hand corned of the floor section, beep 3 times when the move is completed, and then stop.

To successfully complete this laboratory, your robot should be capable of correctly identifying objects encountered and search until a Styrofoam block is found and delivered to the final destination. You will have a maximum of 5 minutes to perform the demo. Note: since each kit contains only one light sensor, you will not be able to update your odometer using the floor gridlines (no correction). It is expected that your estimates will drift, but a one-tile accuracy should still be reachable.

Data/Analysis

Since this lab combines key elements of the previous labs, this will provide an opportunity to evaluate the performance of the “total” system, an important pre-requisite for your project.

1. Perform at least 10 trials of object recognition using an object other than the Styrofoam block and note the number of false positives.
2. Repeat the above step, but using the Styrofoam block each time, noting the total number of false negatives. Ideally both errors should be as small as possible.
3. Run through the search program at least 5 times, recording the average time taken to localize, to find a block, and then to travel to the destination. In the final competition, you must complete localization in less than 30 seconds. Also, estimate your localization and final destination errors for each trial.

These statistics should give you a reasonable idea of how your robot performs key components of the final competition.

Observations and Conclusions

1. What differences, if any, did you observe in the behavior/performance of your earlier code (i.e. localization, odometry, navigation) when combined in a larger system? Explain any

discrepancies. If it turns out that things worked out pretty much as expected, explain how the design of your code contributed.

2. How reliable was your object detection? What factors influence the reliability of object detection? Where would you expect your code to break down? What steps can you take to make detection more robust?
3. What aspect of this lab did you find most difficult? What aspect of this lab did you find most surprising or unexpected?

To Submit

- One document in standard pdf format.
- All code used to produce the results reported in this experiment.