Lab 5: Line Following Robot

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I. Hardware and Software Design

LINE following is a classic robotics problem and has been solved in a myriad of ways. The objective of this challenge is for the robot to follow a line as quickly as possible until it reaches the end, designated by a yellow square. Once at the end, the robot is to search for its home location, using sound information from the audience to guide it. The test environment includes a line which spirals in to a center point as shown in Fig. 1.

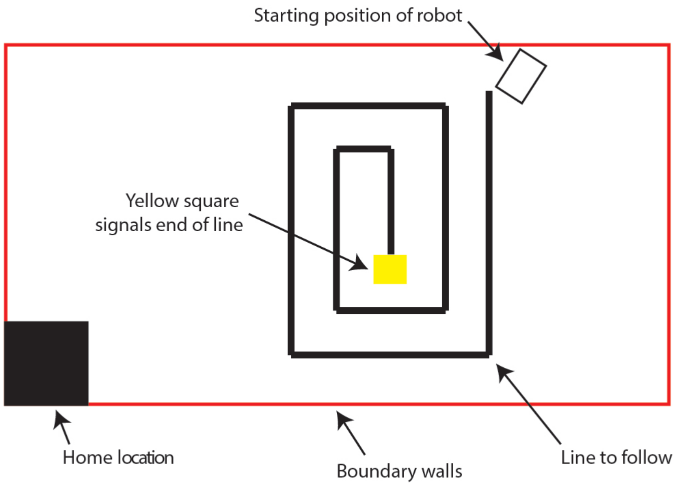

Fig. 1. The test field is rectangular, with a solid black line for the robot to follow. The end of the black line is marked by a solid yellow square. The home location is designated by the solid black square in the lower left corner.

The hardware required for this challenge includes two light sensors, a color sensor and a sound sensor. The light sensors are used to measure reflected light which helps the robot differentiate between the white field and the black line, the color sensor is used to sense the yellow card which marks the end of the line, and the sound sensor is used to tell when the crowd is cheering the robot in the right direction.

The sensors are arranged such that one of the light sensors is on each side of the line at all times, and the color sensor is mounted in the center of the robots path so that it will pass over the yellow square. The sound sensor on the other hand is mounted high above the NXT so that it is located closer to the crowd and also to mitigate the effect of motor noises.

Figure 2 shows the location and orientation of each of the sensors. Because the robot always turns right along the line, the right and left light sensors are offset slightly as shown to avoid getting stuck on a turn. When the sensors are directly beside each other, the potential exists for the left sensor to run over the corner at the same time the right sensor is tripped. This results in the robot thinking that a line is running across the front of it which can cause it to get stuck.

The software design for this challenge is broken into three specific portions. First, because the robot does not start directly on the line it must find it. Next, the robot should follow the line until it reaches the yellow card. Finally, the robot should seek out its home location based on cheering directions from the crowd.

The first part of the program is the method of finding the line. We know which direction the robot will approach the line

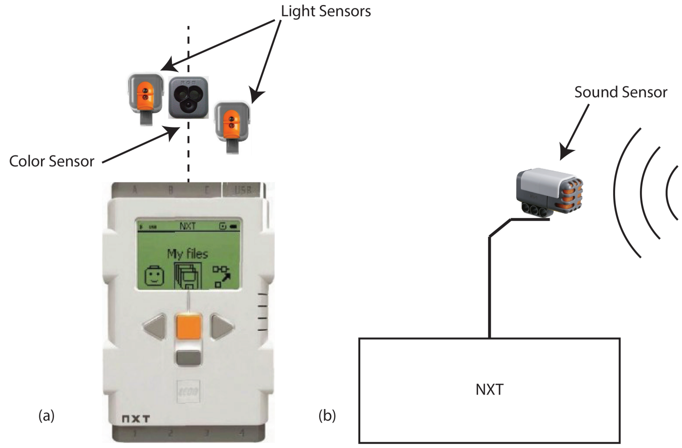

Fig. 2. The overall hardware design is shown from the top view (a) and the side view (b). Note that the light sensors are slightly offset front to back to favor left hand turns.

from, so we tell the robot to move forward until the left sensor sees the line at which point it should turn left until the right sensor has passed over the line once. In all cases, this will result in the robot being centered on the line, and oriented in the right direction.

The line following portion of the program involved the robot checks both the left and right sensors and adjust the motor speeds based on the readings. The left and right motors depend only on the sensor on that side are their speeds are proportionally controlled according to the relationship

$$P_{motor} = \frac{P_{max} - P_{min}}{I_{max} - I_{min}} I_{sensor} + offset \tag{1}$$

where P_{motor} is the calculated motor power, P_{max} and P_{min} are the maximum and minimum power settings for the motors (user configureable), I_{max} and I_{min} are the maximum and minimum sensed values (experimentally determined), and I_{sensor} is the value that the sensor is currently reading. The offset for this equation can easily be calculated in software using all of the user configurable parameters, and the experimentally determined sensor limits by

$$offset = P_{max} - \frac{P_{max} - P_{min}}{I_{max} - I_{min}} I_{max}. \tag{2}$$

The result of these power settings is that the motor speeds increase when further away from the line and decrease and even reverse (if P_{min} is less than zero) when the sensor gets closer to the line. The behavior that this produces in the robot is that the motor speed incrementally decreases as it approaches a line slowly, but when it reaches a corner the power is immediately decreases to its minimum in order to complete the turn.

All throughout the line following portion of the challenge, the robot is monitoring the color sensor to determine if it has reached the end of the line. This is accomplished by running the line following code in a while loop which terminates when the color sensor reads the appropriate value for yellow.

The final part of the challenge is for the robot to find home based on cheering from the crowd. The software used to implement this simply monitors the sound sensor and has two actions. When the noise threshold is below a user configurable value, the robot spins in place but when the noise level is above the threshold, the robot drives in a straight line. This effectively allows the crowd to steer the robot by being quite in order to orient in the correct direction and then cheering to move it straight ahead. Of course, the robot does not drive completely straight, so this process may need to be completed multiple times before reaching the home location.

II. Problems Encountered

III. Solutions

IV. Unsolved Problems