CSCE 236 Embedded Systems, Spring 2015
Project Competition 1

Started: March 5, 2015
Checkpoint: Thursday, March 12, 2015
Competition: Thursday, March 19, 2015
Written Report: Thursday, April 2, 2015

1 Instructions

In this assignment you will implement a line following behavior on your robot using the IR sensors introduced in Lab 4. Ultimately your robot will compete against your classmates' robots on a variety of courses to test the performance of your robot. There are many different ways that you can implement the line following behavior. This project description contains some suggested approaches, but feel free to innovate in your algorithmic approach.

In addition to the competition component of this assignment, there are also some written questions to answer. This is an individual assignment, collaboration is not allowed. If you discuss any problems with others, please note this on the assignment as described in the syllabus.

Make sure to read the all questions for the assignment before you get too far on implementing the line-following as the sensor characterization will help improve your implementation.

2 Project 1 Competition Overview and Approaches

As an overview, this competition will involve having your robot follow a line as quickly as possible using the IR sensors. In addition to speed, your robot will be judged on the smoothness of operation. Your robots will compete against each other on a variety of courses containing different types of curves and turns. Start by mounting the IR sensors on your robot as demonstrated in class. When mounting, you should consider potential advantages or disadvantages to various mounting locations, including distance from the ground, distance from the wheels, and how far apart the sensors are from each other.

The next step is to write code to guide your robot based on the sensor feedback. There are a number of different approaches:

- **Bounce within the line:** Transition between three different driving states (straight, left turn, and right turn) with the goal of keeping both sensors within the line (drive straight when both sensors detect a line). This is challenging since the sensors must be mounted very close together.
- **Straddle the line:** Again, transition between three different driving states (straight, left turn, and right turn) with the goal of keeping one sensor on the line and one off the line (for example, drive straight when left sensor detects a line and right does not).
- **Straddle the inside edge:** Similar to straddling the line, except you add additional logic to try and follow the side of the edge that is on the "inside" of the turn, which will result in a shorter overall distance traveled. One basic approach for implementing this is to maintain a counter that counts the number of times you are turning right versus left. If you are turning left more often, then you should try to straddle the left side of the line since that is the inside. If you are turning right more often, switch to straddling the right edge. How and when you transition from the different modes is important to avoid bouncing back and forth between the different modes and zigzagging within the line.
- There are many other approaches to this problem, how you do it is up to you.

Each of these approaches can also be improved by thinking about the following:

- **Speed:** The faster you go the better for your completion time, but it also makes it more difficult to stay on course. You should experiment with different speeds. You could also implement some speed variation. For instance, keep increasing speed while you are on the line, but slow down if you start needing to turn.
- **Turning rate:** The smoothness of operation also factors into this competition. If you simply switch between hard-left, hard-right, and straight turns your robot will exhibit jerky operation. This type of controller is known as a "bang-bang" control approach. Instead, you could implement a more advanced control approach that has smoother transitions. One idea is to instead control the turn radius in a more incremental fashion. If you go off the left side of the line, just make a small adjustment to turn more to the right. If you are still off the left side, increase it a little more. Once you are back on the line, don't go straight, but rather keep the current turn radius. This can create smoother operation.
- **Sensor positions:** Another factor that impacts your line following ability is how close the sensors are to the ground, how close they are to each other, and how far away they are from the wheels. There are advantages and disadvantages to each possibility and you may want to experiment with different positions. For instance, having the sensors mounted far from the wheels lets small turns move the sensors a lot. This may make for quick responses, but a less smooth operation than if you mounted them directly under the wheels. If you place the sensors far off the ground, the difference between black and white will be small, but you may be able to actually tell the difference between on the line, off the line, and on the edge of the line. Consider these tradeoffs in your design.
- **Lost line:** You should also consider what you do if you completely lose a line. You may want to continue turning in the direction you were turning before, stop and back up, or always turn in one direction. What you do when you lose the line will also depend on your control approach.

Remember, your goal is to make the fastest robot, while keeping it smooth, see Section 3.1 for details on how you will be scored.

3 Course Specifications

In this section the specifications for the courses and scoring are outlined. There will be three courses that will be available on the first floor in the Schorr Center (open 8am-5pm M-F). You will be able to test your robot on these courses. You are expected to have at least basic line following implemented by this time.

Checkpoint: Thursday, March 12, 2015: You must demonstrate basic line following capabilities on the courses in class. At a minimum, you must be able to follow the line in Lab 4.

In addition to the three known courses, there will be one mystery course that will not be revealed until the competition on Thursday, March 19, 2015.

3.1 Scoring

For each of the courses the following scoring rules will apply:

- There are 3 marked points on each course (revealed on the day of the competition). Each point reached will result in 1 point and finishing will result in an additional point. This means you get 4 points for finishing the course.
- The fastest time will get 6 additional points, second 5 points, and third 4 points. Those finishing within the top third of the class (excluding top three) will get 2 points, second third will get 1 additional point.

- The smoothness of your robot operation on the course will be judged with *nearly always smooth* receiving 2 points, *sometimes smooth* receiving 1 point, and *rarely smooth* receiving no additional points. To receive smoothness points you must at least reach the second waypoint.

The order that you do each course will be specified on the day of the competition. Each person will be able to run each course once. If you are not ready to run your robot when it is your turn, you can skip that course and potentially try that course again after everyone else has completed the course (however, your ordering for the rest of the courses will remain fixed). After everyone has completed all the courses, people who skipped a course will have an opportunity to try again, time permitting.

Your overall score will be the summation of your runs on all the courses. The scores will then be sorted to produce a ranking. The ranking in the class will roughly correlate and map to the 10 points allocated for the competition results (see Section 4 for details).

The four courses will be:

- **Regular Lines:** This course will have regular lines with a fixed width between half and 3/4 of an inch wide. There will only be curves in this course, no right angles.
- **Varying Line Width:** This course will have lines with varying widths from as thin as half an inch to extremely wide black regions. Following edges (especially the inside edge) will be advantageous on this course.
- **Sharp Turns:** This course will use the same line width as the regular course, but will include some sharp turns at up to 90 degrees.
- **Surprise Course:** This course will not be revealed until the final competition day. It will contain a mix of all of the above elements.

4 Report and Questions

These questions must be completed and turned in at the start of class on Thursday, April 2, 2015. Some of these questions involve characterizing the sensors and it is highly recommended that you do these before the competition and even before you finalize your robot design. **Use complete sentences when describing and analyzing your results. Most questions can be answered in a few sentences, but some may require more detail.**

Five points of your final project grade will be based on the clarity of your answers, grammar, flow, etc. So make sure you spend time making the report readable.

Note: Your plots must be clearly labeled and the different lines must be identifiable. Make sure the paper version you turn in is legible how you print it (e.g. if you print in B/W, make sure that you can identify the different lines in your plots).

Problem 1 (5pts)**.** *Robots like to have names. What is the name of your robot? Include a picture of your robot in your report.*

Problem 2. *Analog to Digital Converter*

a) (5pts)**.** *How fast did you obtain readings from your sensors? Answer in Hz. Describe how you determined this. You should answer this question for the code you used during the competition (***not** *the maximum rate possible, but what you used).* **Hint:** *If you print frequently to the serial port this will slow down your readings.*

b) (5pts)**.** *On the Arduino, what is the fastest that you could theoretically read the sensors at maximum precision? Is there a difference between the rate you find and the theoretical rate? If so, why? Base your analysis on the information in the datasheet, not just what the Arduino website says.*

c) (5pts)**.** *What is the average value in ADC counts when held steady over white paper? What about black? What are the corresponding voltages for these?*

d) (5pts). *What are the variances in your readings while held steady over black? How many bits in the ADC reading are actually useful (e.g. if you always see 234 and 235, then there is one bit of noise)? Repeat this experiment for over white. Make sure to support your answer with data (plots are helpful).*

Problem 3. *Sensor characterization. Use the last page from Lab 4 for these problems. For this problem you will need to create a program that outputs data from both your sensors at a relatively high speed over the serial port. You can then copy and paste this data into excel or some other program for plotting the results of the data.* **Make sure to properly label all plots for full credit.**

a) (5pts). *Create a plot showing the readings of the sensors as you move the sensor further away (distance above) from a black surface by using a ruler to take measurements at a number of fixed distances. Make sure to include* **at least 6 different readings**. *Do the same experiment over a white surface and also using your second sensor. Plot the results for all of these on a single plot (you should have 4 different lines).* **Describe and analyze the results.** *Consider aspects such as: is there a linear relationship between the distance and the value reported? What is the maximum distance that you can reliably tell the difference between black and white? Do both of your sensors perform the same or are there differences? If there are differences, what do you think caused these? Include any other observations you may have.*

b) (5pts). *The last page of Lab 4 contained a gradient and tick marks next to each other. Drive your robot so that one sensor sees the tick marks and the other sees the gradient. Record and plot data from both sensors when driving slowly across these.* **Describe and analyze the results.** *Consider aspects such as: how sharp a difference is there between seeing a tick mark and not? Is the gradient a linear gradient as reported by the sensor, or something else? And any other observations you may have.*

c) (5pts). *Collect and plot data from both sensors while following the line on the last page of Lab4. Also include output from your control algorithm indicating if you are turning left, right, or going straight. Alternatively if you are using a different control approach, make sure you can visibly see in the plot what control state it is in.* **Describe and analyze the results.**

Problem 4. *Design and control approach.*

a) (5pts). *Include a picture showing where you mounted your sensors. Why did you mount them where you did? Discuss advantages and disadvantages in the mounting location of your sensors.*

b) (5pts). *Describe the control approach(es) you implemented for the competition. Draw a state machine showing the different states you used in your control approach. Also describe strengths and weaknesses of your approach.*

c) (5pts). *Did you end up moving at the maximum possible forward speed or did you go slower? Did you rotate at the maximum rate? Why or why not? If you did go as fast as your robot could go, how much faster do you think you could have gone if you had faster motors?*

Problem 5 (5pts). *Analyze your performance during the competition. How could you have improved your results? What worked well and what did not work well?*

Problem 6. *These subproblems do not require any writeup, but will be based on your performance in the competition.*

a) (10pts). *These points are for achieving the checkpoint on Thursday, March 12, 2015. This involved at a minimum being able to follow the line on the last page of Lab 4. Late checkoffs will not be accepted.*

b) (5pts). *For successful completion of at least one course up to marker 2 on the day of the competition.*

c) (5pts). *For successful completion of at least one full course on the day of the competition.*

d) (5pts). *For successful completion of at least two full courses on the day of the competition.*

e) (10pts). *These points will be allocated roughly proportionally based on your overall score in the competition relative to your classmates.*