CSCE236 PROJECT 1

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Contents

Introduction

For this project, a robot car is designed. The robot can follow a black and white line using the IR sensors. ADC converter, sensor characterization, design and control approach of the robot will be introduced in this report.

Robot Name and Exterior

The robot's name is AX666. AX is the abbreviation of my name and 666 means "pretty good" in Chinese.

Figure 1 shows the front side of the robot. Figure 2 shows the reverse side of the robot.

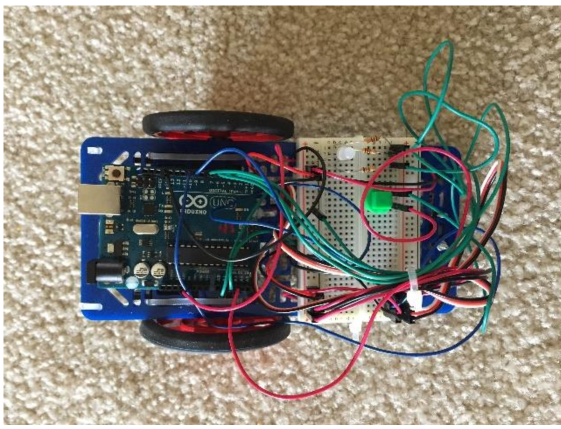

Figure 1

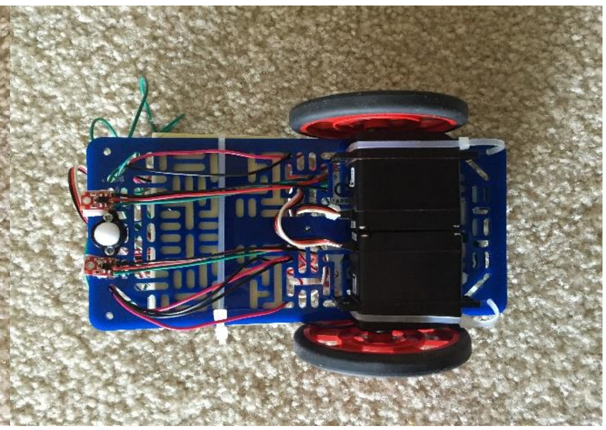

Figure 2

ADC Converter of the Robot

The frequency of the ADC Converter

The frequency of obtaining reading from the sensors is $20HZ$. There are two ways to get the frequency.
The first way is that use the millis() function to get the time interval between each read. Then, use the equation $f = \frac{1}{Interval}$ to get the result.
Another way is that transfer the C code to assemble code first. From the datasheet, the clock cycle of each assemble instruction can be obtained. So the total clock cycle taken between each read can be obtained. Then, the frequency can be obtained.

Difference between Theoretical and Real Rate of the ADC Converter

According to the Atmega328 datasheet, the theoretical rate of the ADC converter is 15kSPS at maximum resolution. Compared with the real rate, which is only 0.02kSPS, the theoretical rate which is much higher than the real rate.

The difference is caused by many reasons. The main reason is that there is extra code followed, which will decide the next state (go straight, turn right, turn left) of the robot and execute it. These extra will take time and reduce the rate. Also, the quality of the sensors will also have an influence on the time taken for the ADC converter. This will also affect the real rate.

The Average Value of ADC and Corresponding Voltage

There are two sensors used in this robot. The average value in ADC counts when held steady over white paper and black paper are different between the two sensors. Table 1 shows the values for both sensors.

Note: based on Figure 2, sensor 1 refers to the sensor above and sensor 2 refers to the sensor below.

	On White Paper	On Black Paper
Sensor 1	843	68
Sensor 2	879	57

Table 1

For the sensor 1 on white paper, the corresponding voltage is $5 * \frac{843}{1024} = 4.12V$.

For the sensor 1 on black paper, the corresponding voltage is $5 * \frac{68}{1024} = 0.33V$.

For the sensor 2 on white paper, the corresponding voltage is $5 * \frac{879}{1024} = 4.29V$.

For the sensor 2 on black paper, the corresponding voltage is $5 * \frac{57}{1024} = 0.13V$.

Variance of the ADC value

There are 10-bit that is actually used in ADC reading.

Note: based on Figure 2, sensor 1 refers to the sensor above and sensor 2 refers to the sensor below.

Figure 3 shows the data obtained by the two sensors when held steady on black.

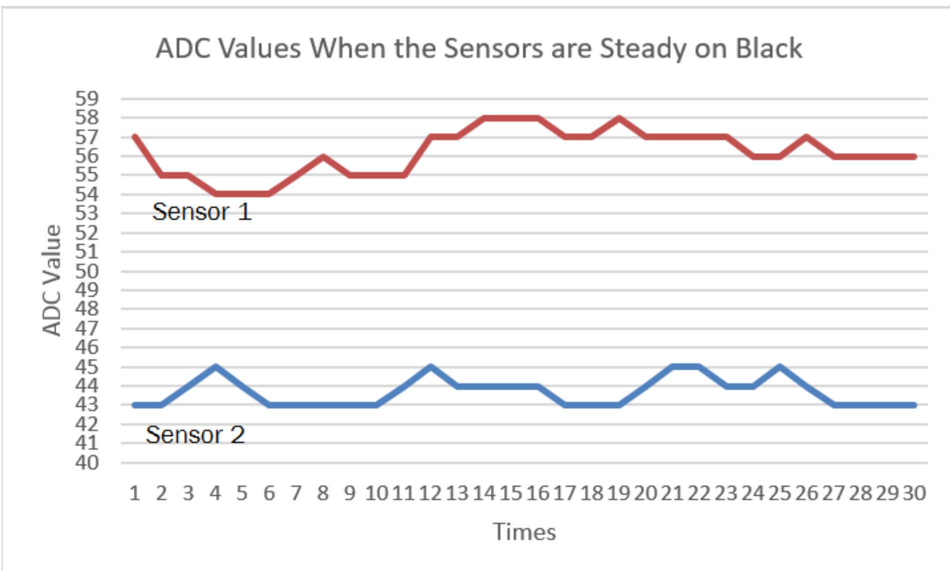

Figure 3

For sensor 1, the variance of the data is 1.10220263. The noise is 2 bits.

For sensor 2, the variance of the data is 0.865859451. The noise is 2 bits.

For both sensors steady on black, the variance is small. The noise is acceptable, which will not affect the result.

Figure 4 shows the data obtained by the sensors when held steady on white.

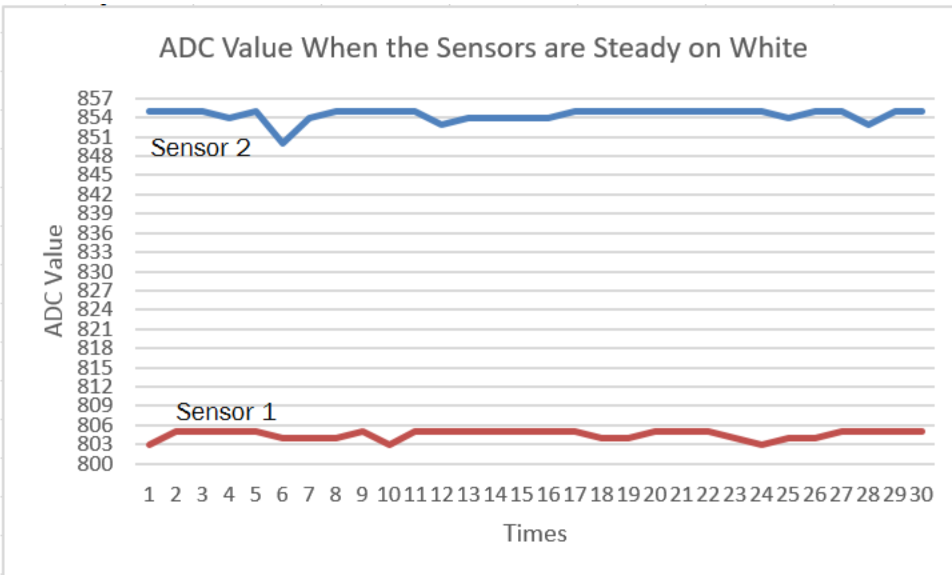

Figure 4

For sensor 1, the variance of the data is 0.825497055. The noise is 2 bits.

For sensor 2, the variance of the data is 1.020617911. The noise is 3 bits.

For both sensors steady on white, the variance is small. The noise is acceptable, which will not affect the result.

Sensor Characterization

The Relationship between Sensor Value and Distance

Figure 5 shows the reading of the both sensors as moving the sensor further away from a black surface and white surface (Note: based on Figure 2, sensor 1 refers to the sensor above and sensor 2 refers to the sensor below).

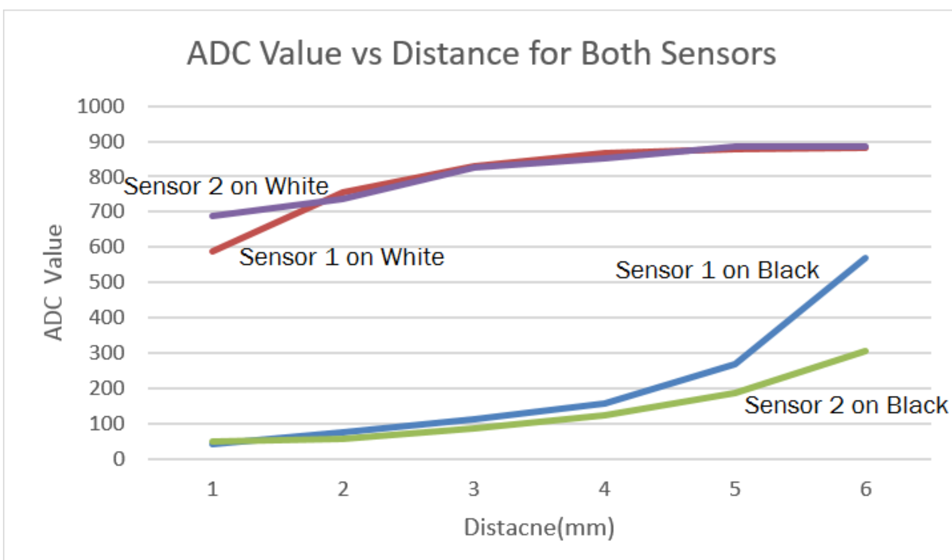

Figure 5

Based on figure 5, for both the two sensors, either on black or white, when the distance is between 1mm and 4mm, the ADC value is nearly linear. However, when the distance is longer than 4mm, if the sensor is on black, the ADC value will jump and be close to the value on white. If the sensor is on white, the ADC value will be continuously close to 900. So the maximum reliable distance of the two sensors is 4mm.

The ADC value of the two sensors are almost same when the distance is same. The difference is caused by the quality of the sensors. The brightness of the test place will also affect the ADC value.

Sensor Values on Tick Mark and Gradient

Figure 6 shows the plot which on senor is on the tick marks and the other is on the gradient (Note: based on Figure 2, sensor 1 refers to the sensor above and sensor 2 refers to the sensor below).

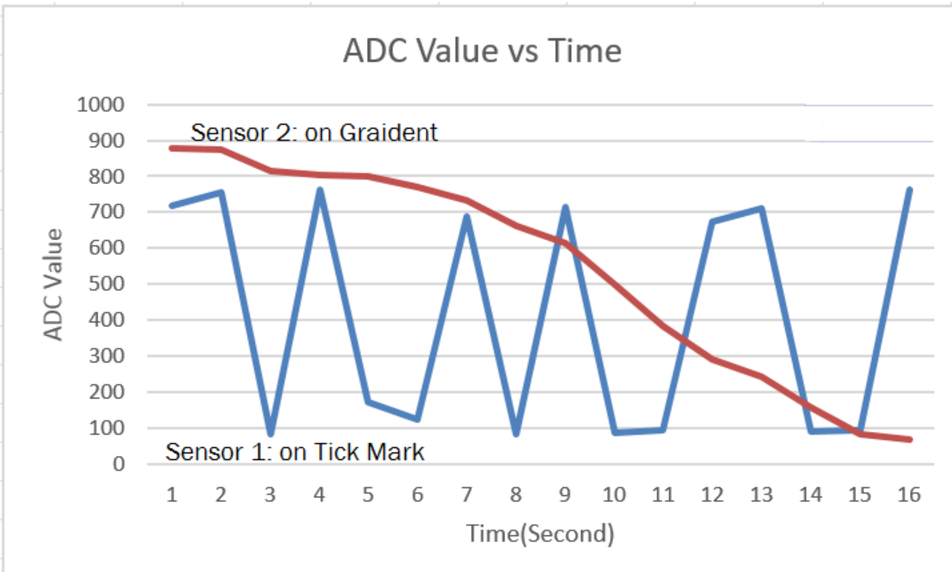

Figure 6

The sensor 1 is moving on the tick mark. Based on Figure 6, the line read by sensor 1 is very sharp. When the sensor is on tick mark, the ADC values are less than 100. When the sensor is on white, the ADC values are greater than 700.

The sensor 2 is moving on the gradient. Based on Figure 6, the line read by sensor 2 is nearly linear. The ADC value reduces gradually when the gradient become more and more dark.

Sensor Value and the State

Based on the data collected above, when the sensors are on black, the average value is below 200. When the sensors are on white, the average is over 600. So 400 is picked as a comparator to determine whether a sensor is on black or white.

Table 2 shows the value of the two sensors and the current state when moving on the line. Note: based on Figure 2, sensor 1 refers to the sensor above and sensor 2 refers to the sensor below.

Sensor 1	Sensor 2	State
60	678	Turn Right
117	788	Turn Right
66	86	Turn Right
836	167	Go Straight
842	128	Go Straight
684	54	Go Straight
100	50	Turn Left
130	50	Turn Left
159	51	Turn Left

Table 2

Based on table 2, it is easy to figure out that whether the sensors is on the black or white can be correctly determined when use 400 as a comparator. Then, the current state can be decided and executed.

The details of the approach will be discussed in the following section.

Design and Control Approach

Sensor Positions

Figure 7 shows the position where the two sensors are mounted.

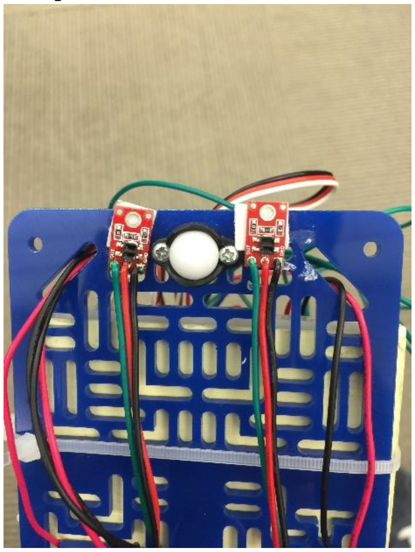

Figure 7

As shown in the figure 7, the two sensors are mounted at the two sides of the nose wheel. The approach used for this robot is straddling the line, which means the robot will keep one sensor on the line and one off the line (The details will be discussed in the next section).

The advantage of mounting the sensors at the sides of the nose wheel is that the sensors can obtain the data before the body of the robot arrives so the robot can have enough time to do the corresponding action (go straight, turn left or turn right) based on the data obtained by the sensors. Also, in this way, it is easy for people to detect whether one sensor is on the line and another sensor is off the line, which is easy for debug.

The disadvantage is that the space between the two sensors are very large. As mentioned above, the approach used is straddling the line. In the situation that the line of a course are close to each other, the sensor which is off the line may occupy another line. This will cause the robot run out of line.

Details of the Control Approach

The approach I used is straddle the line. The left sensor is always off the line and the right sensor is always on the line. There are three basic states, which are go straight, turn right and turn left. These states will change from each other. The movement of the robot is based on that. The next state are decided by the last state and the data from the two sensors. The details will show in the figure 8. Figure 8 shows the state machine diagram of the approach.

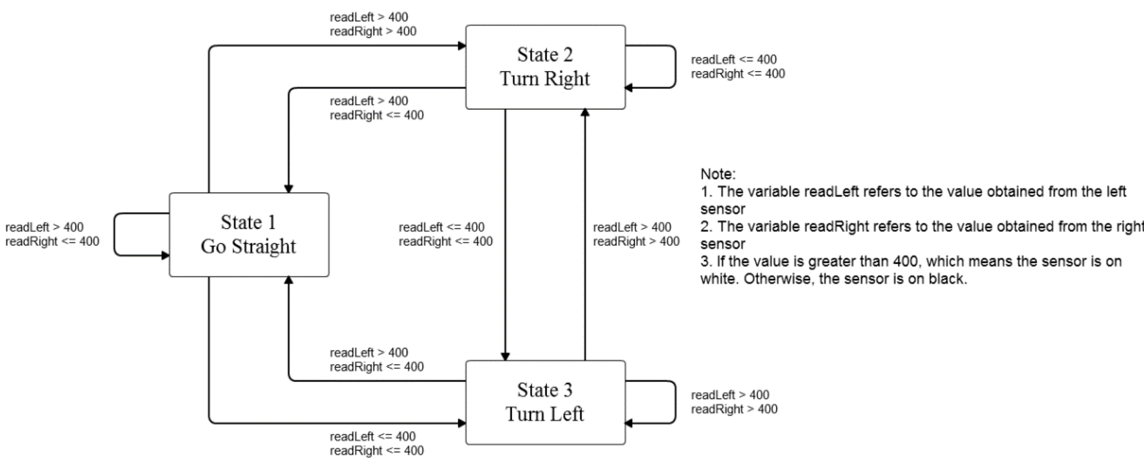

Figure 8

The strength is that the approach used for this robot can make it successfully detect all the paths, even if the turn is very sharp or there is a long straight line, the robot can detect them and follow the line.

The weakness of the approach is that there are only three states. So it is not able to adjust the speed and turning rate corresponding to different turns (sharp turns and smooth turns). This will cause the robot move slowly and not always smoothly.

Speed of the Robot

The robot can't move at the maximum possible speed which the servos can support in all the three states. If the robot move with a faster speed, the processor will not have enough time to change the correct states of the robot in time. This will cause the robot run out of the line. This is a weakness of the robot, which needs to be improved.

Conclusion

During the competition, the robot can successfully complete all the four courses. It can detect the straight line, right turn, left turn and sharp turn correctly. However, the robot still has some weaknesses. It can't keep moving smoothly and fast.

Currently, my robot can only move in three states, which is go straight, turn left and turn right. The improvement can be made on adding more states corresponding to the sharp turns, long straight lines and varying width lines. In this way, the robot can move more smoothly and faster. The result can be improved.