Lab 4: Localization

ECSE 211-Design Principles and Methods

Group Number 62

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DATA:

The robot was programmed with two initial ultrasonic sensor localizations: one, it turns until it is facing the compound, and turns until it gets a near sensor reading signaling the other wall (falling edge;) two, it turns until it faces the wall and keeps turning until it is facing the compound (rising edge.) It then turns until it is facing zero within a certain tolerance. The data for **Falling Edge** is in **Table 1** and the data for **Rising Edge** is in **Table 2**.

TABLE 1: DATA FOR FALLING EDGE

Trial/No.	Odometer Angle/ °(degrees)	Actual Angle/°(degrees)	Error = Actual – Odometer/°(degrees)
1	0	18	18
2	0	0	0
3	0	5	5
4	0	-3	-3
5	0	9	9
6	0	7	7
7	0	0	0
8	0	-2	-2
9	0	-4	-4
10	0	-9	-9

TABLE 2: DATA FOR RISING EDGE

Trial/No.	Odometer Angle/ °(degrees)	Actual Angle/°(degrees)	Error = Actual – Odometer/°(degrees)
1	0	9	9
2	0	25	25
3	0	-16	-16
4	0	6	6
5	0	18	18
6	0	35	35
7	0	-15	-15
8	0	5	5
9	0	10	10
10	0	-9	-9

ERROR CALCULATIONS:

1. **FALLING EDGE**

The mean (μ) of a set of values of N elements can be calculated by summing up all the elements in the set and dividing this total by N. In the case of the error in the falling edge routine, the total values (N) are **10**, and the sum of all the elements in this particular set is **21**. Dividing this number by **10** gives **2.1**, which is the mean of error in the falling edge routine.

Calculation for Standard Deviation of Error for Falling Edge:

To calculate the standard deviation (σ), we use the following formula:

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \mu)^2}$$

In the formula shown above to calculate σ, N represents the number of values in the set like in the calculation of the mean, x represents a certain value in the set at i position i, where i is less than or equal to the value of N, and μ is the mean of the set calculated above for both the errors.

As the formula suggests, we start off by subtracting the mean of the set from each individual value in the set to produce a new set of values. This gives us the following set of values:

(15.9, -2.1, 2.9, -5.1, 6.9, 4.9, -2.1, -4.1, -6.1, 11.1)

Next, we square each of these values to obtain the following:

(252.81, 4.41, 8.41, 26.01, 47.61, 24.01, 4.41, 16.81, 37.21, 123.21)

We sum these values and obtain, **544.90**. We divide this by N-1, which is 9. The result of this is, **60.54.**

Finally, to get the standard deviation, we take the square root of 60.54, which yields **7.78103~7.78**. This is the standard deviation of the Falling Edge routine.

2. **RISING EGDE**

In the case of the error in the rising edge routine, the total values (N) again are 10, and the sum of all the elements in this particular set is **68**. Dividing this number by 10 gives us **6.8**, which is the mean of error in the rising edge routine.

Calculation for Standard Deviation of Error for Rising Edge:

Like we showed above for Falling Edge, we start off by subtracting the mean of the set from each individual value in the set to produce a new set of values. This gives us the following set of values:

(2.2, 18.2, -22.8, -0.8, 11.2, 28.2, -21.8, -1.8, 3.2, -15.8)

We square the elements of this set, that yields the following result

(4.84, 331.24, 519.84, 0.64, 125.44, 795.24, 475.24, 3.24, 10.24, 249.64)

Summing these values gives us, **2515.4,** We divide this by N-1, which is 9, this yields, 279.4888. Finally, we take the square root of this value, and get our standard deviation for the error in Rising Edge. The value is **16.71792~16.72**

OBSERVATIONS AND CONCLUSIONS:

1. ***Which of the two localization routines performed the best? Which performed the worst? What factors do you think contributed to the performance (or lack thereof) of each method?***

Based on our above data and its subsequent analysis we can conclude that the Falling Edge routine was far more accurate than Rising Edge routine. This is cemented by the fact that the mean angle error of the Falling Edge routine was **2.1** degrees as compared to the **6.8** degrees' error of the Rising Edge routine. As we conducted further statistical analysis of our data we discovered there was considerable difference in the standard deviations of the two aforementioned routines of ultrasonic localization, with the falling edge routine, the clear better of the two having an angle standard deviation of **7.78**, as compared to the rising edge standard deviation of **16.72.**

The factors which contributed to the better performance of the falling edge routine were the essential operation of each of the methods of localization. The falling edge routine operates firstly by rotating and then latching onto the angle at which it detects a wall followed by switching the direction of rotation and doing the same once again. The rising edge, however operates in a completely opposite manner. It latches onto the angle at which it can no longer detect a wall. These positions were specified for both routines through a software implementation whereby we programmed a certain threshold distance at which to latch onto an angle.

After rigorous testing of both routines, we have come to the conclusion that the reason the falling edge routine is more accurate was due to its ability to latch onto the angle where it first sees a wall, which means that when the Ultrasonic s ensor (US) samples a distance lower than the threshold distance provided, there was is angle calculated. Conversely, the rising edge routine latches the angle where it cannot see the wall (i.e. a distance higher than the threshold distance provided), which means that if the US sensor (which based on the results of Lab 1 is prone to more false negatives than false positives), does not detect a wall when there is one present, will latch onto an angle more inaccurate than that obtained by the falling edge routine, resulting in greater errors and subsequently yielding higher values for mean and standard deviation.

2. ***Why does the light sensor provide a more accurate means of orienting the robot than the ultrasonic sensor?***

The light sensor is a more accurate means of localization due to several reasons. Firstly, the light sensor is placed very close to the ground, this decreases the error in the light sensor as it travels across the grid. The US sensor on the other hand can vary in distance from the walls it detects, as a result this gives rise to error in the US sensor.

Another reason the light sensor is more accurate than the US is due to the fact the light sensor has a smaller port opening and proximity, this results in greater resolution than the US, making it more accurate for measurement.

The light sensor operates on the principles of reflection of light as a wave, which is exponentially faster than sound waves as implemented by the US sensor (3x10^8 m/s compared to 340 m/s). This, coupled with a greater sampling rate allows it to compute more data per unit time, and thus making it a far more accurate and reliable device for measurement.

3. ***Propose a means of determining (approximately) the initial position of the robot using the ultrasonic sensor (Hint: Consider the minima of the ultrasonic sensor's readings as the robot rotates). Why is detecting minima with the ultrasonic sensor problematic?***

Upon careful consideration and investigation, we consider the following procedure to be a method of getting the initial position of the robot by using the US. Firstly, we rotate the robot about its initial starting position and set the nearest intersection of grid lines as the origin. As the robot starts rotating, the ultrasonic sensor starts to move as well and eventually it will face a wall. At this point it will begin detecting a distance that is lower than the threshold distance implemented, this distance will start decreasing and eventually reach minima. Based on our observations and understanding, we assumed this minima to be the first time a perpendicular distance from the wall was achieved.

After this minima, the distance will start to increase until it reaches a maximum distance which is lower than the threshold, we can assume this to be the 45-degree line on the grid, where the two walls used in localization come together and cut each other.

The distance will again start decreasing and reach another minima, which we assume to be the second time a perpendicular distance from the robot to the wall is achieved. These two perpendicular distances represent the x and y axes positions of the robot's orientation, and the x and y positions with respect to the origin can be calculated using the known length of the grid lines (30x30). Depending on what the y and x axes were assumed at the start of the experiment, we can calculate the position as ((30-minima1), -(30-minima2)), with the negative sign depending on the assumed orientation of the x and y axes.

FUTURE IMPROVEMENTS

1. ***Propose a way to avoid small errors more accurately than a clipping filter?***

The clipping filter is a very crude method for removing irrelevant values because it only accepts values from the sensor that are within a certain range, and all values outside this range are ignored. An alternative that we propose to the clipping filter would be to use a limiter. The limiter would greatly assist in reducing small errors. It would reduce the signal being processed by the US sensor, this in turn would prevent the signal from being completely clipped after a certain value. The reason clipping is such a problem is because it causes considerable data loss and brings about small errors in processing and calculation. By limiting the signal, the small signal would not be clipped, and as a result the small errors in detection and calculation could be considerably decreased.

2. ***Propose a sensor design that would result in a more accurate and reliable reading than an ultrasonic sensor.***

After careful analysis of various sensors and their subsequent design implementations, we feel an infrared sensor would provide a suitable sensor design for more accurate and reliable readings in comparison to an US. The infrared sensor has a greater sampling rate so despite it having a smaller operating range than US, the use of infrared waves to detect proximity is more accurate and reliable than US which is far more susceptible to noise and signal distortion. Also, the smaller operating range of the infrared sensor in the lab environment is ideal, as a 50 cm operating range would yield much more accurate results.

3. ***Propose another form of localization than rising-edge or falling-edge.***

We feel another form of localization that could be used is a technique employing two light sensors and an ultrasonic sensor instead of a single light sensor and an US sensor together. Let's suppose that the robot is in the bottom corner square of the assigned grid for this experiment and we know the dimensions of each unit in the grid, we would firstly rotate the robot and detect the local minima and maxima as detailed above in the Observations and Conclusions section. This would in theory, allow us to know the initial orientation of the robot as the localization process begins. Then using the data that is collected, the robot could be navigated to the grid lines on the grid provided. The two light sensors will detect any offset in the angular orientation of the robot. Passing through both the adjacent grid lines would provide us with adequate data concerning the error in heading of the robot using the two light sensors mounted on the robot. These errors could be used to calibrate the angle using the **setPosition()** method which we implemented in the **Odometer class.** This method of localization would help us to achieve maximum accuracy in localization. Although it is slightly more tedious than the localization of the lab we just performed, this method would bring considerable accuracy to our findings.