Test Document

Project: LIBERTY
Task: Localization Test

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1.0 TESTS

Test 1: Localization facing away from wall

Date: 3/11/2017
Tester: Edward Son
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1) The purpose of this test is to validate that the addition of the funnel will not affect the robot's ability to localize using the ultrasonic sensor when starting facing away from the corner.
2) The objective of this test is to measure the maximum and minimum distance from the point (1,1) that the robot can still localize using ultrasonic sensor.
3) First, measure with a ruler 1cm from the (1,1) along the 45 degree line, and place the robot at this distance, facing away from the corner. Then, run falling edge ultrasonic localization. This consists of the ultrasonic detecting a falling edge while turning -360 degrees, which is when the current detected distance is under a threshold of 50, and the previous distance is over 100. Also, the alpha angle should not yet be set. Once detected, set alpha from odometer using "alpha = Math.toDegrees(odometer.getTheta());", then turn 360 degrees. Using the same condition and when alpha does not equal 0, detect the next falling edge. Set beta using "beta = Math.toDegrees(odometer.getTheta());". Then, calculate the real angle error using the following conditions:

```
if (alpha < beta) {
        deltaTheta = 55 - (alpha - beta) / 2;
      } else {
        deltaTheta = 265 - (alpha - beta) / 2;
      }
}
```

   Finally, set the odometer theta to deltaTheta. Repeat the first step, but increment the distance, until the robot does not successfully complete ultrasonic localization.
4) The expected plot is a scatter plot of values close to 0, which represents a success in the ultrasonic localization. The angle does not need to be perfect at this point, since light localization will take care of the angle error. Also, where this plot will end is going to be considered the maximum distance from (1,1) that the robot can successfully localize.
5)

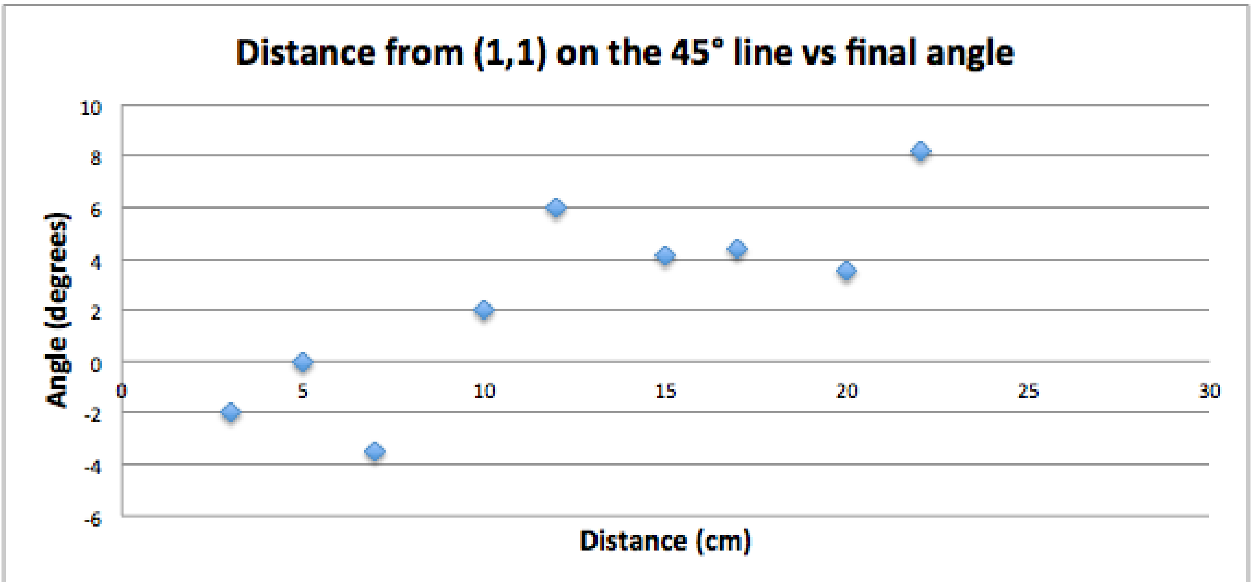


Figure 1: Distance v.s. final angle after localization

6) As seen from the graph above, the robot successfully localizes from a distance of 3 cm up to 22 cm down the 45 degree line from (1,1) to (0,0). The reason 22 cm is the maximum, is because the funnel attached to the front of the robot prevents the robot from turning enough to detect a falling edge.
7) Using this information, we can safely assume that the funnel does not prevent the robot from localizing when starting facing away from the wall. However, we will need to make sure that it is not placed further than 22 cm from the nearest corner, as it will not be able to complete ultrasonic localization. There have been some problems with detecting the falling edge in certain tests, which seems to be due to the front light sensor interfering with the ultrasonic data. Thus, the hardware team should move to displace the light sensor towards the right.

Test 2: Localization facing corner

Date: 3/11/2017
Tester: Edward Son
Author: Edward Son

1) The purpose of this test is to validate that the addition of the funnel will not affect the robot's ability to localize using the ultrasonic sensor when starting facing the corner.
2) The objective of this test is to measure the maximum and minimum distance from the point (1,1) that the robot can still localize using ultrasonic sensor.

3) First, measure with a ruler 1cm from the (1,1) along the 45 degree line, and place the robot at this distance, facing the corner. Then, run falling edge ultrasonic localization. Refer to ***Test 1*** from this section for falling edge implementation. Repeat the first step, but increment the distance, until the robot does not successfully complete ultrasonic localization.
4) The expected plot is a scatter plot of values close to 0, which represents a success in the ultrasonic localization. The angle does not need to be perfect at this point, since light localization will take care of the angle error. Also, where this plot will end is going to be considered the maximum distance from (1,1) that the robot can successfully localize.
5)

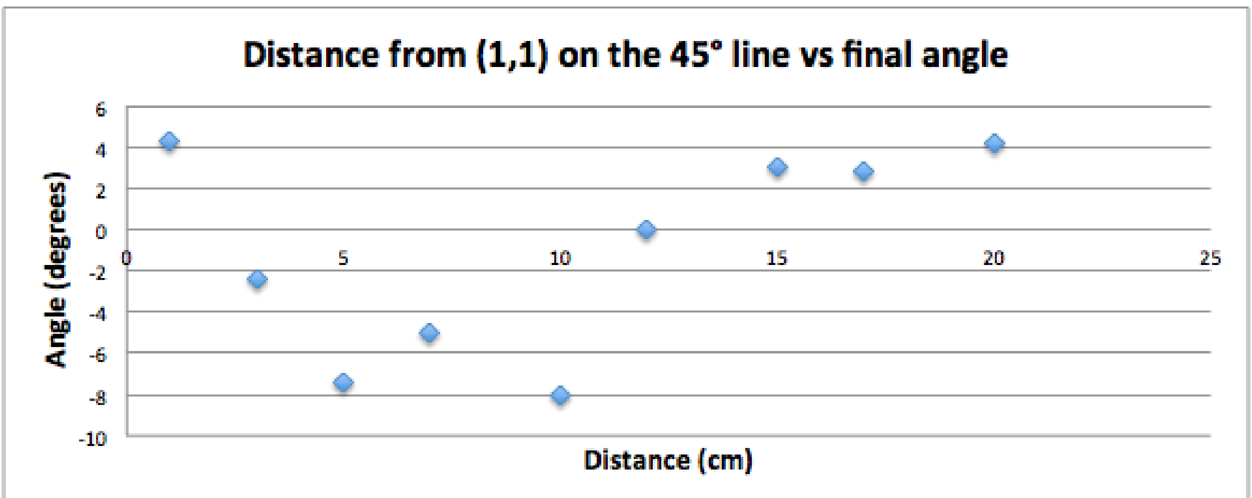


Figure 2: Distance vs final angle after localization

6) As seen from the graph, the robot successfully localizes from a distance of 1 cm to 20 cm down the 45 degree line from (1,1). The reason 20 cm is the maximum, is because the funnel attached to the front of the robot prevents the robot from turning enough to detect a falling edge.
7) Using this information, we can safely assume that the funnel does not prevent the robot from localizing when starting facing toward the wall. However, we will need to make sure that it is not placed further than 20 cm from the nearest corner, as it will not be able to complete ultrasonic localization.

Test 3: Ultrasonic Localization and Light Localization Accuracy

Date: 14/11/2017
Tester: Claire Liu

Author: Claire Liu

1) The purpose of this test is to determine the accuracy of the localization.
2) One objective of this test is to determine the difference of the actual zero degree and the zero degree that the robot turns to after ultrasonic localization. The other objective is that to identify the difference of the real x-position, y-position and theta with 30.48cm, 30.48cm and 0 degree respectively.
3) First, keep the robot start at point (18.0cm, 18.0cm). Then, run the testing code in the ultrasonic localization mode and record the starting position, which increases by 30 degrees each time. After the robot finishes localizing, record the actual theta of its direction and compute the difference of it with the actual zero degree. Next, run the light localization process. When it finishes, record the actual position of the robot and the (30.48cm, 30.48cm), which is the crossing of the grid line. In addition, record the final angle after light localization and compare it to the actual zero degree. After the starting position reaches 360 degrees, move the robot to (26.5cm, 26.5cm) and then start from the second step.
4) The actual angle after ultrasonic localization should be within 340 degrees and 20 degrees. Moreover, after localization, both actual x position and y position of the robot should be within 27.48cm to 33.48. Meanwhile, the theta should be within 355 degrees and 5 degrees.
5) Results:

	ultrasonic localization(starting point (18.00, 18.00))			light localization		
trial	start angle (+/- 1deg)	ending angle(+/- 1 deg)	comment	x (+/- 1cm)	y (+/- 1cm)	theta(+/- 1 deg)
1	0	4.5		31.18	30.68	4.7
2	30	12.8		31.48	30.48	5.6
3	60	6.4		30.48	30.68	5.4
4	90	7.6		30.68	31.08	5.5
5	120	4.6		31.08	30.48	4.6
6	150	8	(first time failed)	30.58	30.58	4.5
7	180	6.3		31.48	30.88	5.3
8	210	3.7	(first time failed)	30.48	31.38	4.2
9	240	3.3	(first time failed)	30.48	30.48	4.6
10	270	6.7		31.48	30.98	6
11	300	failed				
12	330	7.9		31.38	30.48	5.9
	average	6.5273				
	standard deviation	2.662				

Figure 1: Testing Result of Both UL and LL Process at Point (18.00cm, 18.00cm)

Trial	offset		
	x (+/- 1cm)	y (+/- 1cm)	theta(+/- 1 deg)
1	0.7	0.2	4.7
2	1.0	0.0	5.6
3	0.0	0.2	5.4
4	0.2	0.6	5.5
5	0.6	0.0	4.6
6	0.1	0.1	4.5
7	1.0	0.4	5.3
8	0.0	0.9	4.2
9	0.0	0.0	4.6
10	1.0	0.5	6
11			
12	0.9	0.0	5.9
average	0.5	0.2636	5.118
standard deviation	0.4	0.301	0.618

Figure 2: Offset of the Final Position with Start Point of (18.00cm, 18.00cm)

trial	ultrasonic localization(starting point (26.5, 26.5))			light localization		
	start angle (+/- 1deg)	ending angle(+/- 1 deg)	comment	x (+/- 1cm)	y (+/- 1cm)	theta(+/- 1 deg)
1	0	4.7		31.18	30.48	6.4
2	30	10	350 actually	31.08	30.68	6.8
3	60	5		31.18	30.48	5.3
4	90	6.5		31.48	30.78	4.9
5	120	5		31.08	30.78	3.2
6	150	4.3			failed	
7	180	6.9		31.38	31.48	5.8
8	210	3.5			failed	
9	240	4.3		31.18	30.48	4.2
10	270	8.7		31.48	30.58	7.2
11	300	5.6	failed for 3 times		failed	
12	330	7.3		32.48	30.88	7.2
	average	5.983				
	standard deviation	1.952				

Figure 3: Testing Result of Both UL and LL Process at Point (26.50cm, 26.50cm)

Trial	offset		
	x (+/- 1cm)	y (+/- 1cm)	theta(+/- 1 deg)
1	0.7	0.0	6.4
2	0.6	0.2	6.8
3	0.7	0.0	5.3
4	1.0	0.3	4.9
5	0.6	0.3	3.2
6			
7	0.9	1.0	5.8
8			
9	0.7	0.0	4.2
10	1.0	0.1	7.2
11			
12	2.0	0.4	7.2
average	0.911	0.256	5.667
standard deviation	0.4	0.317	1.392

Figure 4: Offset of the Final Position with Start Point of (26.50cm, 26.50cm)

6) From Figure 1, it can be observed that the overall result of the ultrasonic localization at point (18.00cm, 18.00cm) is perfectly within the expected range, except for the starting

angle of 300 degrees. Meanwhile, comparing to the corresponding data from Figure 3, the starting angle of 300 degrees is extremely easy to fail. What happed there is that the ultrasonic sensor detected the left wall twice, and then fail to finish the localization.

From the comment column of Figure 1, the fact that when the ultrasonic localization process starts facing towards the wall, the ultrasonic sensor usually gets incorrect data and ruins the result can be obtained. This is due to the character of the sensor.

For the light localization process, the result from the point of (18.00cm, 18.00cm) is perfectly. The expected position of the robot can be travelled to and the average and the standard deviation of the offset respect to the estimated point are small and acceptable. However, the light localizing process failed in three of the trials at the point of (26.50cm, 26.50cm). This is because the starting point is too close to the grid line and after ultrasonic localization, one of the light sensor has already detected the first grid line on the y axis. Thus, the robot starts the light localization immediately with the first detected direction along the y-axis.

Finally, when the robot finishes the localization, it turns too slightly. The expected 90-degree turn is usually 5-degree smaller in actual.

7) The best range for placing the robot should be from (18.00cm, 18.00cm) to (24.00cm, 24.00cm) exclusively along the diagonal. The 24.00cm is approximately the half-distance of the two light sensors subtracts the length of the block, which is 30.48cm.

   The robot does not turn enough and should turn 5 degrees more in terms of a 90-degree turning.

The average (AM) was calculated by using the following formula

$$Average = \frac{1}{n}\sum_{i=1}^{n} a_i = \frac{1}{n}(a_1 + a_2 + \cdots + a_n)$$

We use the sample standard deviation formula (see below) to calculate the sample standard deviation.

$$s = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \overline{x})^2}$$

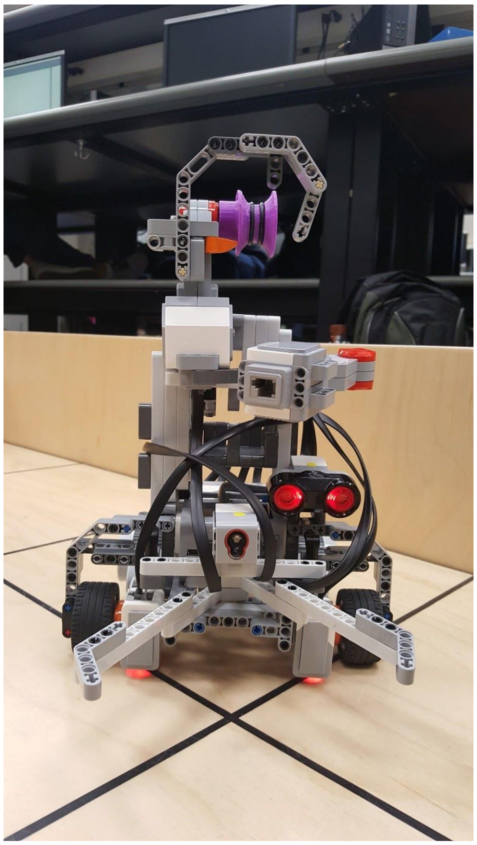
$\overline{x}$ = *Mean*

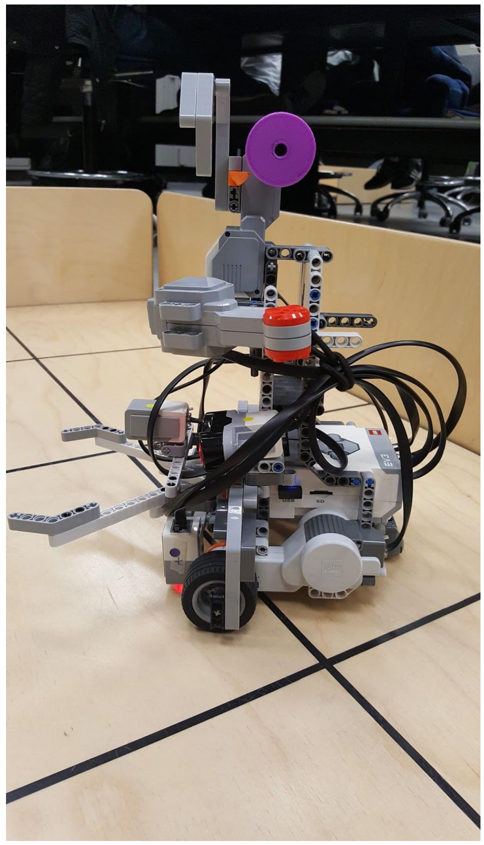
N = *Sample size*

x_i = *Sample at i*

$$\frac{1}{n} \sum_{i=1}^{n} a_i = \frac{1}{n} (a_1 + a_2 + \cdots + a_n)$$

2.0 HARDWARE





See ***HARDWARE - 2.0.***

3.0 Source Code used

See github group repository at commit: `ece3f482ff5a8c32efee6b44eef19bdfd2c32df0`