# TESTING DOCUMENT

**Project**: Final DPM Project
**Document Version:** 1.0
**Date:** 20/10/2018
**Author:** Ashish
**Edit history:**
[18/10/2018] Ashish: Created Testing Document
[22/10/2018] Ashish: Completed some tests
[28/10/2018] Ashish: Added more tests
[30/10/2018] Ashish: Added results from previous tests and made changes to the structure of the document
[3/11/2018] Ashish: Added test 2, 4 & 6
[5/11/2018] Ashish: Added test 7, 8, & 9

## Table of contents

# 1.0 Requirements

## 1.1 Project requirements

see Requirements document

## 1.2 Testing Requirements

- Each test should note: date, testers, author, hardware version, software version, goal, procedure, expected result, test report, conclusion, action and distribution.
- Each test should have at least 10 trials.
- Weak points should be tested exhaustively
- Testers should have a clear expected outcome for each test.

## 1.3 General Test Procedures

- Test whether the hardware design is stable when moving and turning.
- Test whether the robot can light localize accurately
- Test whether the robot can ultrasonic localize accurately
- Test whether the robot can correctly detect the color of the ring.
- Test whether the robot can correctly turn to any direction
- Test whether the robot can correctly travel to any coordinate after localization

# 2.0 Testing Plan

## 2.1 Hardware

- Hardware stability (Incomplete)
    - The center of gravity needs to be center of the robot so that the robot has equal weight distribution and does not lean on one side, affecting navigation.
- Large EV3 motor performance (Incomplete)
    - The motors need to be accurate when moving around the field at different speeds. The motors that are selected need to be of similar performance to make sure the robot navigates properly.
- Ultrasonic sensor (Incomplete)
    - The ultrasonic sensor must be accurate to ensure the requirements of ultrasonic localization and obstacle avoidance are met

- Light sensor (Incomplete)
    - The light sensor must be accurate to ensure the requirements of light localization and ring color detection are met.

**2.2 Software**

- Navigation (Incomplete)
    - The navigation algorithm must accurately move the robot to any given co-ordinate on the field. The accuracy should be such that when the robot re-localizes, it should be at the correct co-ordinate
- Ultrasonic localization (completed)
    - The ultrasonic localization algorithm must have an accuracy of 10 degrees.
- Light localization (completed)
    - The light localization algorithm must have an accuracy of less than 2cm and an angle of less than 5 degrees
- Ring Color detection (Incomplete)
    - The color detection algorithm must accurately determine the color of the ring up to 5cm away from the light sensor.

## 3.0 Tests

Test 1: Ultrasonic localization I (Falling edge)
**Date:** 20/10/18
**Tester:** Ashish
**Author:** Ashish
**Hardware Version**: 1.0
**Software Version:** N/A

**Goal:** Determine if the robot can localize reliably.

**Procedure:** Place the robot facing away from the wall on the left corner tile. Run ultrasonic localization and record the angle.

**Expected result:** The robot should turn clockwise and detect the wall when it is within 30cm and record it. Then the robot turns anticlockwise till it detects the wall again and record it. The robot will then compute 0 degrees and turn to it.

**Test Report:** the test was performed 10 times and the results are shown in the table below.

| Run | US Angle(degrees) |
|---|---|
| 1 | 6 |
| 2 | -2 |
| 3 | 3 |
| 4 | 0 |
| 5 | -5 |
| 6 | 4 |
| 7 | -1 |
| 8 | 2 |
| 9 | 4 |
| 10 | 0 |
| Mean: | 1 |
| Standard Deviation: | 3 |

**Conclusion:** The robot always localized within 6 degrees which is within the acceptable margin of error. It should be noted that this test was done when the battery was outputting at 8.0V and accurate localization is not guaranteed for anything less than 8.0V.

**Action:** No further testing is required unless the hardware configuration is changed.

**Distribution:** Software Development, Project management

Test 2: Ultrasonic localization II (Falling edge)
**Date:** 20/10/18
**Tester:** Ashish
**Author:** Ashish
**Hardware Version**: 1.1
**Software Version:** N/A

**Goal:** Determine if the robot can localize reliably.

**Procedure:** Place the robot facing away from the wall on the left corner tile. Run ultrasonic localization and record the angle.

**Expected result:** The robot should turn clockwise and detect the wall when it is within 30cm and record it. Then the robot turns anticlockwise till it detects the wall again and record it. The robot will then compute 0 degrees and turn to it.

**Test Report:** the test was performed 10 times and the results are shown in the table below.

| Run | US Angle(degrees) |
|---|---|
| 1 | 10 |
| 2 | 7 |
| 3 | 6 |

| | |
|---|---|
| 4 | 8 |
| 5 | 11 |
| 6 | 12 |
| 7 | 3 |
| 8 | 9 |
| 9 | 9 |
| 10 | 5 |
| Mean: | 8 |
| Standard Deviation: | 2.64 |

The angles are mostly greater than 5 degrees. The standard deviation is also too large. The robot did not localize with an acceptable margin of error

**Conclusion:** Ultrasonic localization is not reliable.

**Action:** This report will be sent to the hardware and software team to make necessary changes.

**Distribution:** Software Development, Hardware Development, Project management

Test 3: Light localization I (2 light sensors)
**Date:** 20/10/18
**Tester:** Ashish
**Author:** Ashish
**Hardware Version**: 1.0
**Software Version:** N/A

**Goal:** Determine if the robot can light localize reliably.

**Procedure:** Place the robot facing away from the wall on the left corner tile. Run the ultrasonic localization and record the angle. After ultrasonic localization finishes run the light localization and record angle and the distance.

**Expected result:** The values should be close to zero.

**Test Report:** the test was performed 10 times and the results are shown in the table below

| Run | US Angle(degrees) | Euclidean error(cm) | Final Angle(degrees) |
|---|---|---|---|
| 1 | 6 | 0.1 | 2 |
| 2 | -2 | 1.3 | -3 |
| 3 | 3 | 0.4 | 4 |
| 4 | 0 | 0.6 | 1 |
| 5 | -5 | 1.5 | -2 |
| 6 | 4 | 1.1 | 6 |

| | | | |
|---|---|---|---|
| 7 | -1 | 0.1 | -4 |
| 8 | 2 | 1.9 | 5 |
| 9 | 4 | 0.3 | 3 |
| 10 | 0 | 1 | 2 |
| Mean: | 1 | 0.8 | 1 |
| Standard Deviation: | 3 | 0.6 | 3 |

**Conclusion:** The robot always localized within 5 degrees and 2cm from (0,0) which is within the acceptable margin of error. It should be noted that this test was done when the battery was outputting at 8.0V and accurate localization is not guaranteed for anything less than 8.0V.

**Action:** No further testing is required unless the hardware configuration is changed.

**Distribution:** Software Development, Project management

Test 4: Light localization I (2 light sensors)
**Date:** 20/10/18
**Tester:** Ashish
**Author:** Ashish
**Hardware Version**: 1.1
**Software Version:** N/A

**Goal:** Determine if the robot can light localize reliably.

**Procedure:** Place the robot facing away from the wall on the left corner tile. Run the ultrasonic localization and record the angle. After ultrasonic localization finishes run the light localization and record angle and the distance.

**Expected result:** The values should be close to zero.

**Test Report:** the test was performed 10 times and the results are shown in the table below

| Run | US Angle(degrees) | Euclidean error(cm) | Final Angle(degrees) |
|---|---|---|---|
| 1 | 10 | FAILED | FAILED |
| 2 | 7 | 1.0 | 3 |
| 3 | 6 | FAILED | FAILED |
| 4 | 8 | 1.6 | 2 |
| 5 | 11 | FAILED | FAILED |
| 6 | 12 | 3.2 | 2 |
| 7 | 3 | FAILED | FAILED |
| 8 | 9 | FAILED | FAILED |
| 9 | 9 | 2.1 | 3 |
| 10 | 5 | 1.9 | 2 |
| Mean: | 8 | N/A | N/A |

| | | | |
|---|---|---|---|
| Standard Deviation: | 2.64 | N/A | N/A |

When testing the light localization, the light sensor failed to detect lines in 5 out of the 10 trials and therefore failed the test.

**Conclusion:** Light localization is not reliable

**Action:** This report will be sent to the hardware and software team to make necessary changes.

**Distribution:** Software Development, Hardware Development, Project management

Test 5: Ring color detection
**Date:** 22/10/18
**Tester:** Ashish
**Author:** Ashish
**Hardware Version**: N/A
**Software Version:** N/A

**Goal:** To record the RGB values of each ring.

**Procedure:** Place the light sensor 2 cm away from the ring. Press any button on the robot and record the RGB values that are printed on the console. Collect 18 samples of RGB values. Repeat same procedure for the other 3 rings.

**Expected result:** The RGB values should give a gaussian distribution.

**Test Report:** The test was performed 18 times for each of the 4 rings. The mean and standard deviation was calculated using the following formulas:

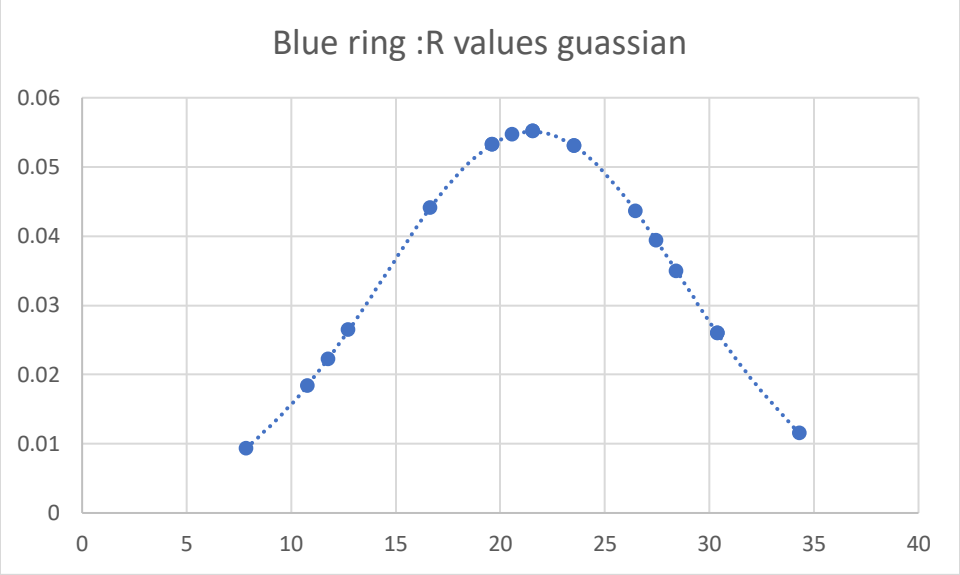
$$mean = \frac{\sum_{i=0}^{n} Si}{n} \qquad stddev = \sqrt{\sum_{i=0}^{n} \frac{(Si-mean)^2}{n-1}}$$

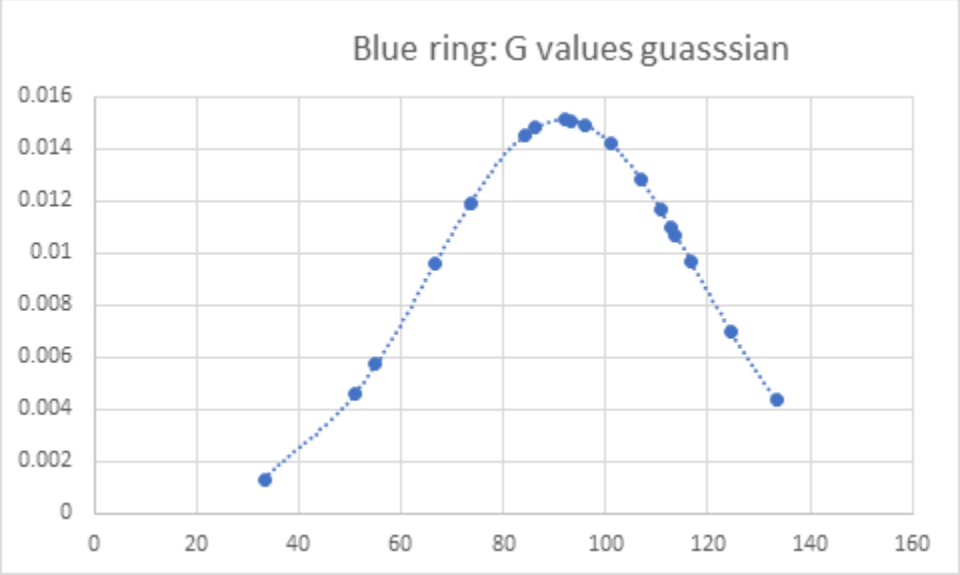
The tables and graphs below show the results:

For the blue ring:

| | R | G | B |
|---|---|---|---|
| 1 | 11.76471 | 54.90196 | 53.92157 |
| 2 | 21.56863 | 92.15687 | 61.76471 |
| 3 | 7.843138 | 33.33334 | 29.41176 |
| 4 | 16.66667 | 73.52941 | 62.7451 |
| 5 | 19.60784 | 84.31373 | 54.90196 |
| 6 | 23.52941 | 106.8628 | 93.13726 |
| 7 | 27.45098 | 112.7451 | 95.09804 |
| 8 | 26.47059 | 113.7255 | 85.29412 |

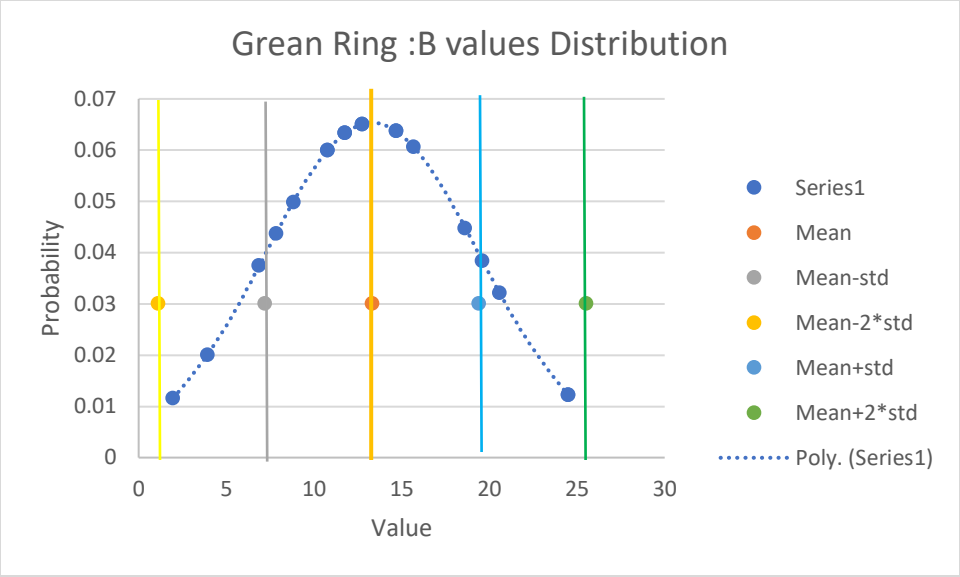
| | | | |
|---|---|---|---|
| 9 | 12.7451 | 66.66667 | 50 |
| 10 | 21.56863 | 96.07843 | 72.54903 |
| 11 | 10.78431 | 50.98039 | 39.21569 |
| 12 | 28.43137 | 110.7843 | 100.9804 |
| 13 | 30.39216 | 124.5098 | 112.7451 |
| 14 | 34.31373 | 133.3333 | 112.7451 |
| 15 | 30.39216 | 116.6667 | 103.9216 |
| 16 | 23.52941 | 100.9804 | 90.19608 |
| 17 | 19.60784 | 86.27451 | 72.54903 |
| 18 | 20.58824 | 93.13726 | 74.5098 |
| Mean | 21.51416 | 91.72113 | 75.87146 |
| STD.dev | 7.237454 | 26.37606 | 26.37606 |

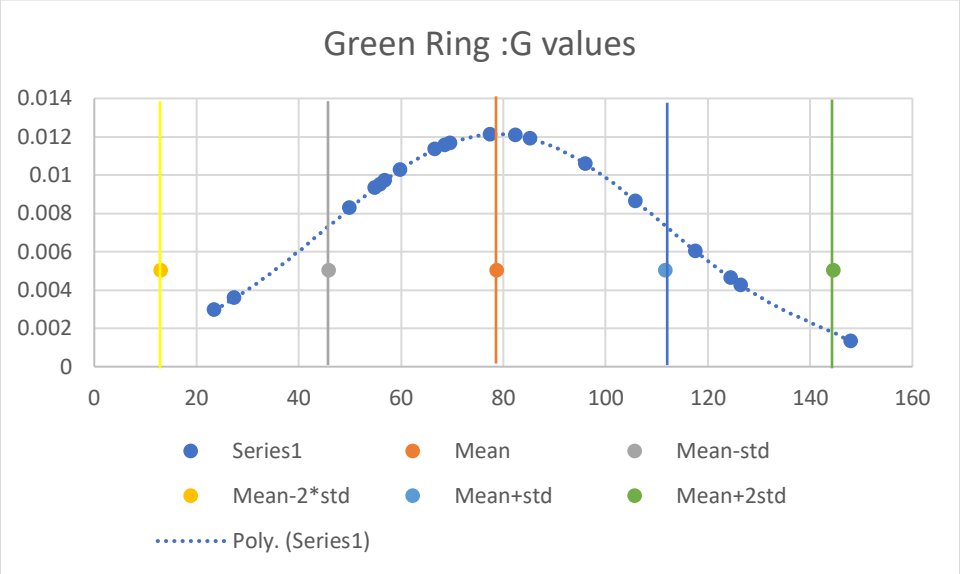


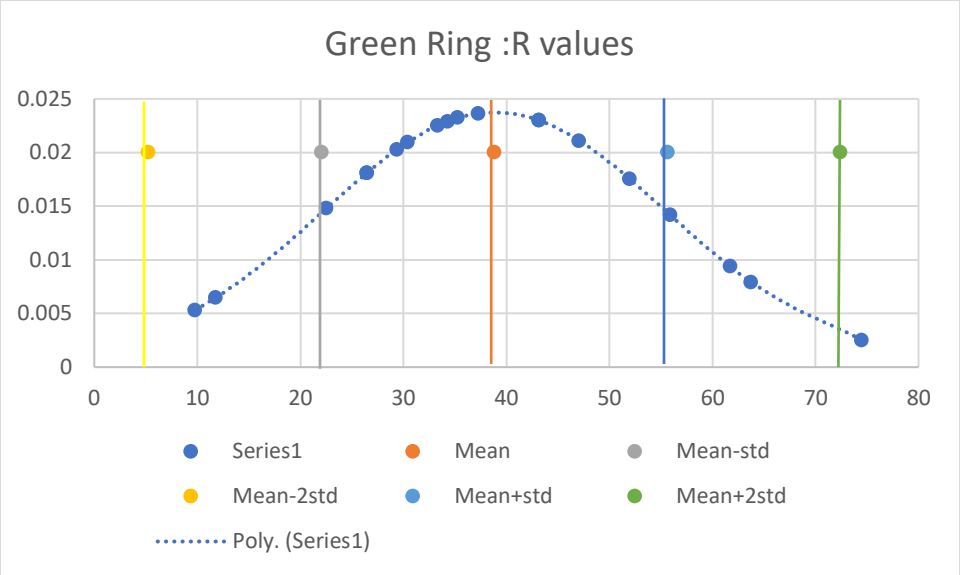




For the green ring :

| | R | G | B |
|---|---|---|---|
| 1 | 43.13726 | 82.35294 | 14.70588 |
| 2 | 35.29412 | 66.66667 | 12.7451 |
| 3 | 61.76471 | 124.5098 | 18.62745 |
| 4 | 63.72549 | 126.4706 | 24.5098 |
| 5 | 43.13726 | 85.29412 | 14.70588 |
| 6 | 11.76471 | 27.45098 | 3.921569 |
| 7 | 26.47059 | 55.88236 | 6.862745 |
| 8 | 51.96079 | 105.8824 | 20.58824 |
| 9 | 33.33334 | 68.62746 | 11.76471 |
| 10 | 29.41176 | 56.86275 | 10.78431 |
| 11 | 55.88236 | 117.6471 | 19.60784 |
| 12 | 22.54902 | 50 | 7.843138 |
| 13 | 34.31373 | 69.60785 | 11.76471 |
| 14 | 30.39216 | 59.80392 | 10.78431 |
| 15 | 47.05882 | 96.07843 | 15.68628 |
| 16 | 37.2549 | 77.45098 | 12.7451 |
| 17 | 74.5098 | 148.0392 | 24.5098 |
| 18 | 26.47059 | 54.90196 | 8.82353 |
| 19 | 9.803922 | 23.52941 | 1.960784 |
| Mean | 38.85449 | 78.79257 | 13.31269 |
| STD.dev | 16.79279 | 32.88598 | 6.104473 |

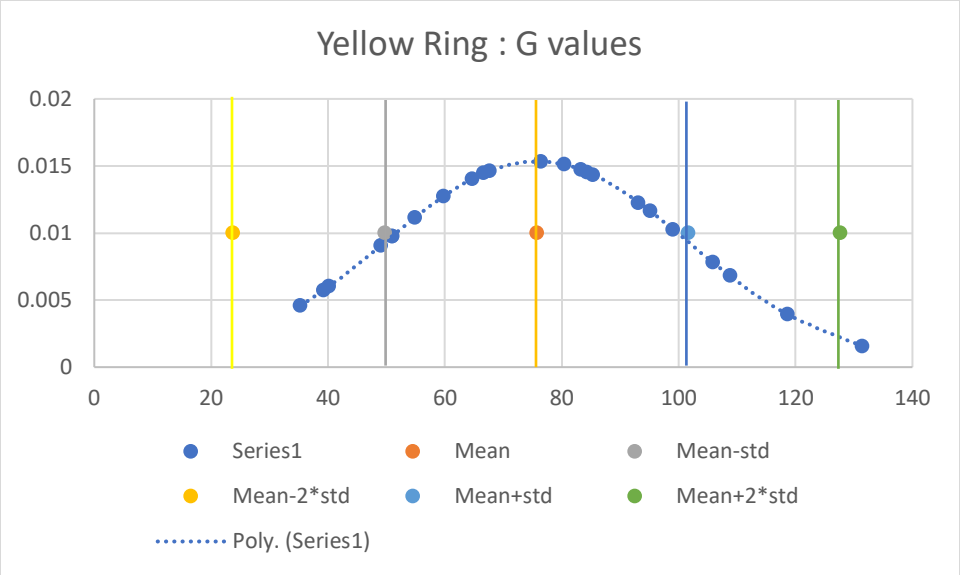

Grean Ring :B values Distribution
Probability
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20
25
30
Value
Series1
Mean
Mean-std
Mean-2*std
Mean+std
Mean+2*std
Poly. (Series1)

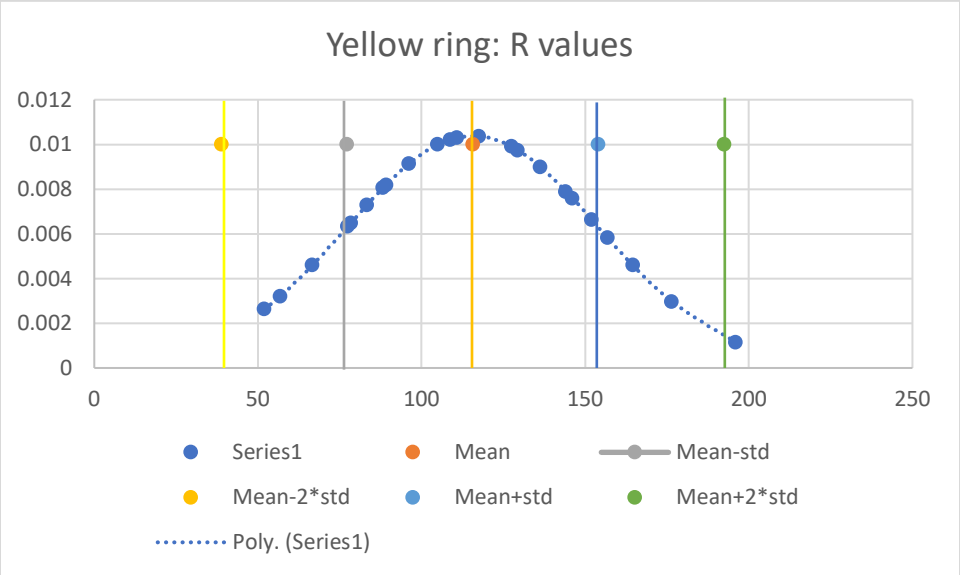

Green Ring :G values
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
20
40
60
80
100
120
140
160
Series1
Mean
Mean-std
Mean-2*std
Mean+std
Mean+2std
Poly. (Series1)

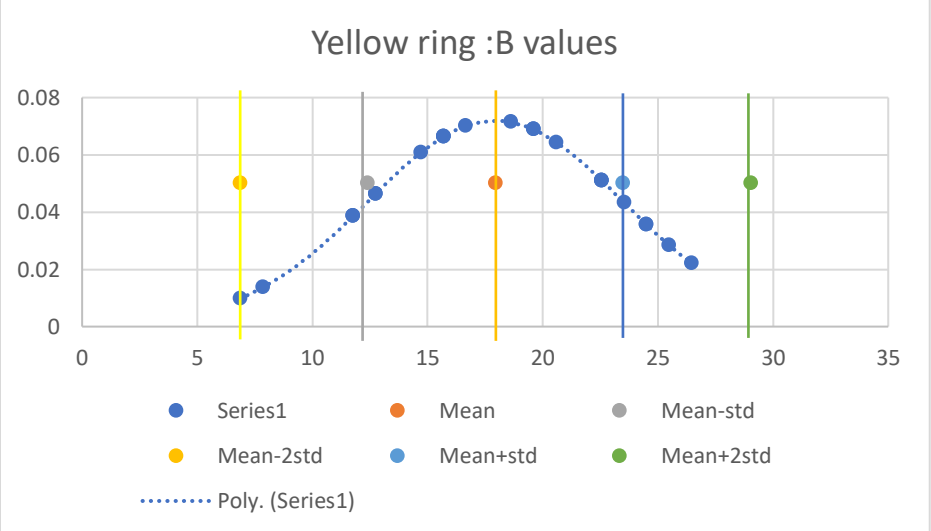



For the yellow ring:

| | R | G | B |
|---|---|---|---|
| 1 | 117.6471 | 80.39216 | 18.62745 |
| 2 | 127.451 | 83.33334 | 20.58824 |
| 3 | 88.2353 | 59.80392 | 12.7451 |
| 4 | 56.86275 | 39.21569 | 7.843138 |
| 5 | 51.96079 | 35.29412 | 6.862745 |
| 6 | 104.902 | 66.66667 | 16.66667 |
| 7 | 108.8235 | 67.64706 | 19.60784 |
| 8 | 96.07843 | 64.70589 | 14.70588 |
| 9 | 110.7843 | 76.47059 | 15.68628 |
| 10 | 156.8628 | 105.8824 | 22.54902 |
| 11 | 146.0784 | 93.13726 | 24.5098 |
| 12 | 66.66667 | 40.19608 | 12.7451 |
| 13 | 77.45098 | 50.98039 | 11.76471 |
| 14 | 78.43137 | 49.01961 | 11.76471 |
| 15 | 83.33334 | 50.98039 | 15.68628 |
| 16 | 89.21569 | 54.90196 | 15.68628 |
| 17 | 129.4118 | 84.31373 | 19.60784 |
| 18 | 176.4706 | 118.6275 | 25.4902 |
| Mean | 115.6437 | 75.70333 | 17.94544 |
| STD.dev | 38.39451 | 25.98696 | 5.541675 |

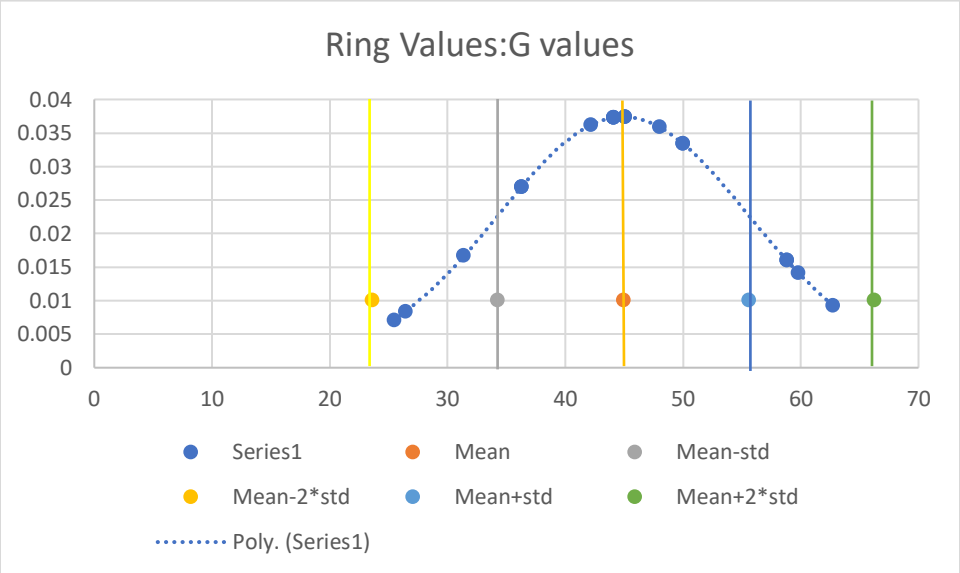

Yellow Ring : G values
0.02
0.015
0.01
0.005
0
0
20
40
60
80
100
120
140
Series1
Mean
Mean-std
Mean-2*std
Mean+std
Mean+2*std
Poly. (Series1)

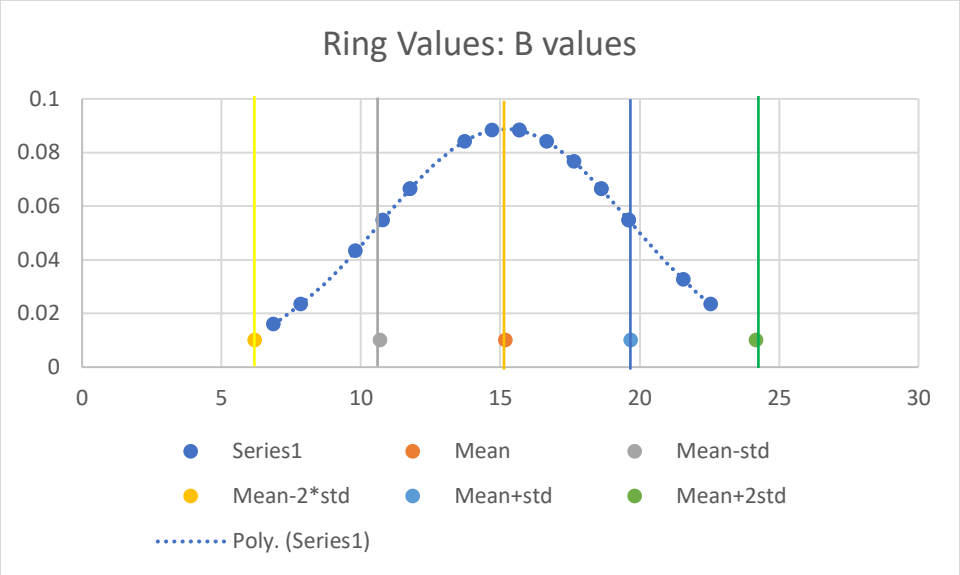

Yellow ring: R values
0.012
0.01
0.008
0.006
0.004
0.002
0
0
50
100
150
200
250
Series1
Mean
Mean-std
Mean-2*std
Mean+std
Mean+2*std
Poly. (Series1)

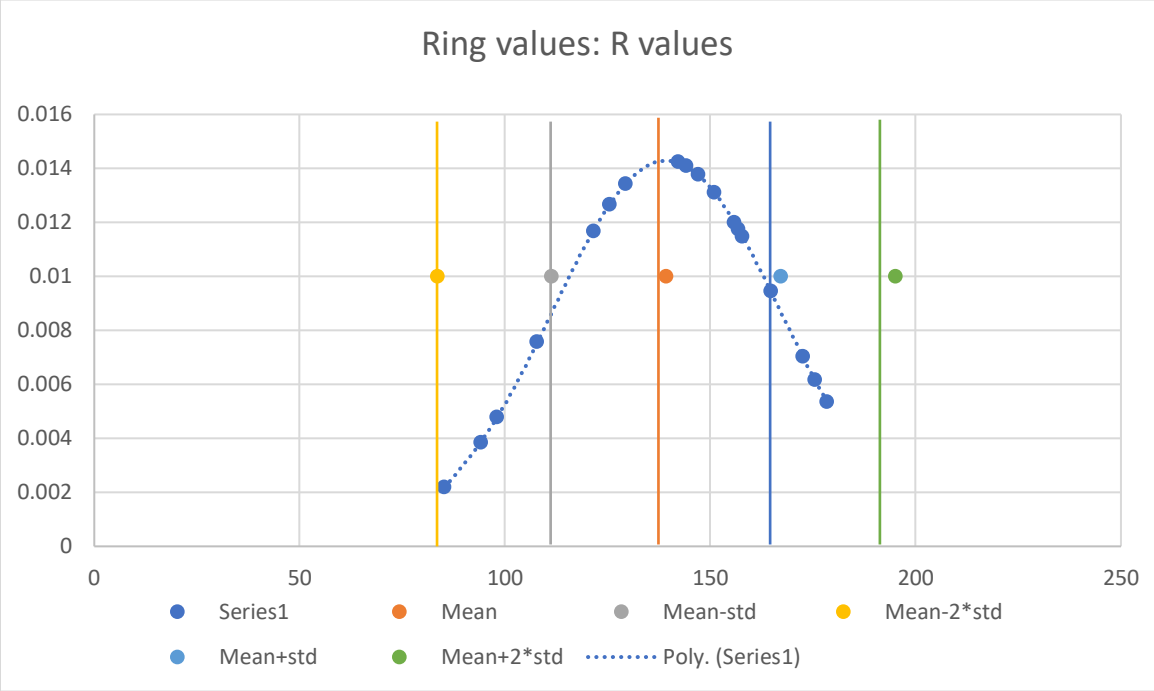

Yellow ring :B values
0.08
0.06
0.04
0.02
0
0
5
10
15
20
25
30
35
Series1
Mean
Mean-std
Mean-2std
Mean+std
Mean+2std
Poly. (Series1)

For the orange ring:

| | R | G | B |
|---|---|---|---|
| 1 | 178.4314 | 59.80392 | 18.62745 |
| 2 | 142.1569 | 45.09804 | 16.66667 |
| 3 | 155.8824 | 50 | 15.68628 |
| 4 | 164.7059 | 58.82353 | 19.60784 |
| 5 | 98.03922 | 31.37255 | 7.843138 |
| 6 | 121.5686 | 42.15686 | 11.76471 |
| 7 | 107.8431 | 36.27451 | 9.803922 |
| 8 | 85.29412 | 25.4902 | 6.862745 |
| 9 | 147.0588 | 50 | 13.72549 |
| 10 | 157.8431 | 45.09804 | 21.56863 |
| 11 | 94.11765 | 26.47059 | 11.76471 |
| 12 | 144.1177 | 44.11765 | 14.70588 |
| 13 | 156.8628 | 44.11765 | 17.64706 |
| 14 | 175.4902 | 58.82353 | 22.54902 |
| 15 | 125.4902 | 36.27451 | 15.68628 |
| 16 | 172.549 | 62.7451 | 19.60784 |
| 17 | 129.4118 | 44.11765 | 10.78431 |
| 18 | 150.9804 | 48.03922 | 18.62745 |
| Mean | 139.3246 | 44.93464 | 15.19608 |
| STD.dev | 27.88884 | 10.66607 | 4.495692 |






**Conclusion:** The test results shows that we can use the RGB values to detect the color of the ring accurately.

**Action:** The test report will be sent to the software team to make an accurate ring detection algorithm using the results.

**Distribution:** Software Development, Project management

Test 6: Ultrasonic accuracy test

**Date:** 3/11/18
**Tester:** Ashish
**Author:** Ashish
**Hardware Version**: 1.0
**Software Version:** N/A

**Goal:** To determine which ultrasonic sensor is the best for our use case

**Procedure:** Place the robot one grid length away from the wall and then 2 grid lengths away from the wall. Press any button on the robot to record the distance from the ultrasonic sensor

**Expected result:** The sensors will read the distance from the wall and display the results on the console. The distances read from the sensors should have an error of less than 2cm.

**Test Report:** The test was done 10 times for each grid length for each sensor and the data is in the table below:

| | 1st sensor | | 2nd sensor | | 3rd sensor | |
|---|---|---|---|---|---|---|
| **Trial** | **Distance (30.48cm)** | **distance (60.96cm)** | **Distance (30.48cm)** | **distance (60.96cm)** | **Distance (30.48cm)** | **Distance (60.96cm)** |
| 1 | 30 | 60 | 30 | 61 | 29 | 60 |
| 2 | 32 | 60 | 32 | 63 | 33 | 60 |
| 3 | 30 | 61 | 30 | 63 | 32 | 62 |
| 4 | 30 | 61 | 32 | 62 | 31 | 64 |
| 5 | 32 | 61 | 30 | 61 | 33 | 61 |
| 6 | 32 | 61 | 32 | 60 | 33 | 61 |
| 7 | 32 | 61 | 32 | 63 | 33 | 61 |
| 8 | 32 | 61 | 30 | 63 | 32 | 62 |
| 9 | 32 | 60 | 31 | 62 | 31 | 62 |
| 10 | 32 | 60 | 30 | 61 | 31 | 63 |
| STD.dev | 0.916515139 | 0.489897949 | 0.943398113 | 1.044030651 | 1.2489996 | 1.2000000 |
| Mean | 31.4 | 60.6 | 30.9 | 61.9 | 31.8 | 61.6 |

From the data, all the sensors produced values close to the actual distance from the wall therefore we had to look at the standard deviation to decide on what sensor to choose. The first sensor had the smallest standard deviation.

**Conclusion:** We decided to choose the first sensor for ultrasonic localization

**Action:** The report is to be sent to the hardware team to make the changes to the robot

**Distribution:** Hardware development, Project Management

Test 7: Light Poller

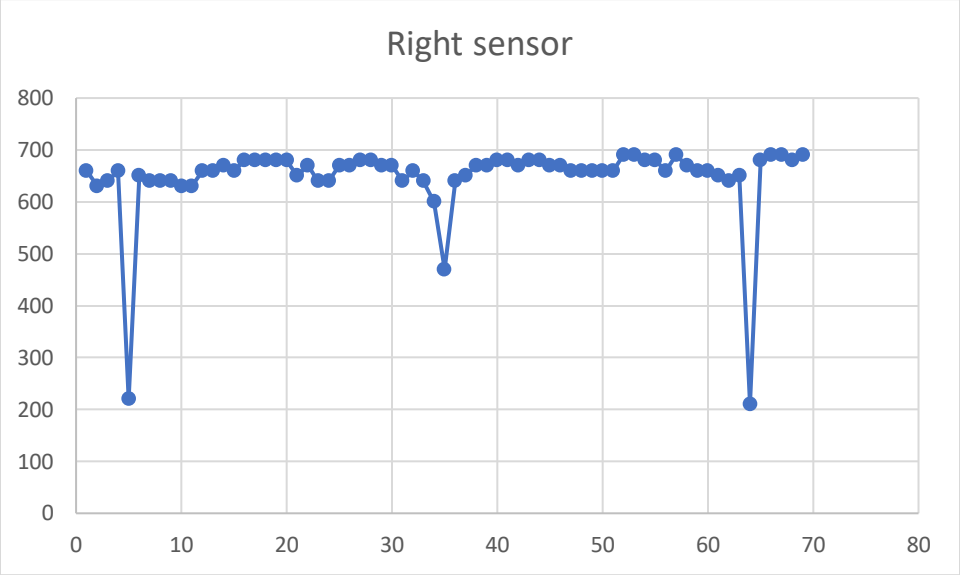
**Date:** 5/11/18
**Tester:** Ashish
**Author:** Ashish
**Hardware Version**: 1.1
**Software Version:** N/A

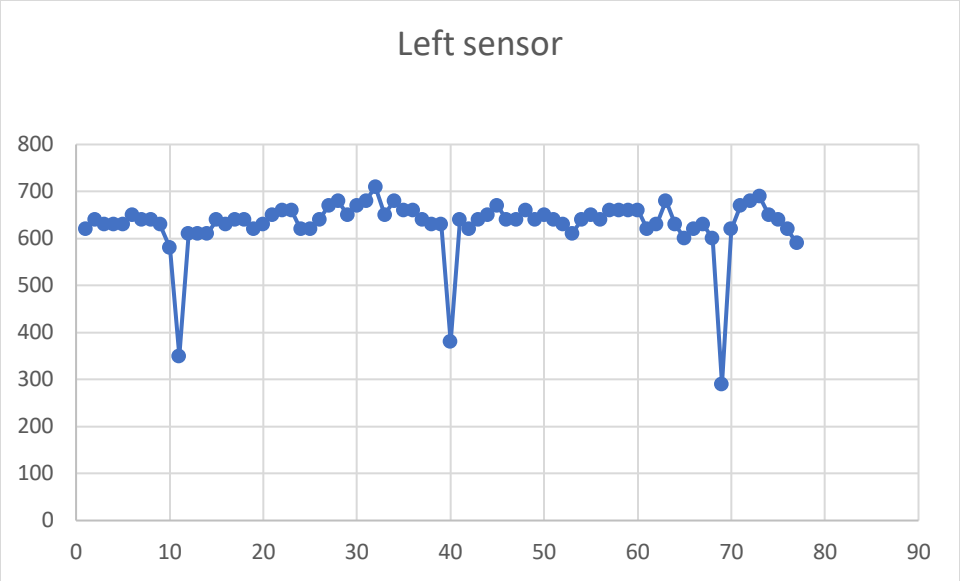
**Goal:** To determine the light differential required to accurately detect the lines on the board.

**Procedure:** Place robot in the middle of the tile and run data acquisition test. The values from the light sensor are displayed on the console. Record the values and plot a scatter graph.

**Expected result:** The graph should show when the lines are detected by the sensor.

**Test Report:** The robot went over 3 lines and the graphs below show the results.






The dips in the graph are when the sensor detects the lines.

**Conclusion:** A differential of 100 would allow the light sensor to accurately detect lines

**Action:** This report will be sent to the software team to make necessary changes.

**Distribution:** Software development, Project Manager

Test 8: Ring detection

**Date:** 5/11/18
**Tester:** Ashish
**Author:** Ashish
**Hardware Version**: 1.1
**Software Version:** N/A

**Goal:** To determine the reliability of ring color detection.

**Procedure:** Run color detection test. Place a ring 2cm away from the light sensor and press any button on the robot. Record the color displayed on the console. Repeat 15 times and get the probability of the correct color detection. Repeat for all the rings.

**Expected result:** The rings should accurately detect the color for 2cm and 4cm but may not correctly detect the ring for 6cm because the light sensor does not work accurately at that distance.

**Test Report:** The tables below show the results:

| Distance (2cm) | | | | |
|---|---|---|---|---|
| | Ring | | | |
| | Blue | Green | Yellow | Orange |
| Trial | | | | |
| 1 | Blue | Green | Yellow | Orange |
| 2 | Blue | Green | Yellow | Orange |
| 3 | Blue | Green | Yellow | Orange |
| 4 | Blue | Green | Yellow | Orange |
| 5 | Blue | Green | Yellow | Orange |
| 6 | Blue | Green | Yellow | Orange |
| 7 | Blue | Green | Yellow | Yellow |
| 8 | Blue | Green | Yellow | Orange |
| 9 | Blue | Green | Orange | Orange |
| 10 | Blue | Green | Yellow | Orange |
| 11 | Blue | Green | Yellow | Orange |
| 12 | Blue | Blue | Yellow | Orange |
| 13 | Blue | Green | Yellow | Orange |
| 14 | Blue | Green | Yellow | Orange |
| 15 | Blue | Green | Yellow | Orange |
| Accuracy | 100% | 93.33% | 93.33% | 93.33% |

| Distance (4cm) | | | | |
|---|---|---|---|---|
| | Ring | | | |
| | Blue | Green | Yellow | Orange |
| Trial | | | | |
| 1 | Blue | Green | Orange | Orange |
| 2 | Blue | Green | Orange | Orange |
| 3 | Blue | Blue | Yellow | Orange |
| 4 | Blue | Green | Yellow | Orange |
| 5 | Blue | Green | Yellow | Orange |
| 6 | Blue | Green | Yellow | Orange |
| 7 | Blue | Green | Yellow | Orange |
| 8 | Blue | Green | Yellow | Orange |
| 9 | Blue | Green | Yellow | Orange |
| 10 | Blue | Green | Yellow | Yellow |
| 11 | Blue | Green | Yellow | Orange |
| 12 | Blue | Green | Yellow | Orange |
| 13 | Blue | Green | Yellow | Orange |
| 14 | Blue | Green | Yellow | Orange |
| 15 | Blue | Green | Yellow | Orange |
| Accuracy | 100% | 93.33% | 86.67% | 93.33% |

| Distance (6cm) | | | | |
|---|---|---|---|---|
| | Ring | | | |
| | Blue | Green | Yellow | Orange |
| Trial | | | | |
| 1 | Blue | Green | Orange | Orange |
| 2 | Blue | Green | Yellow | Yellow |
| 3 | Blue | Green | Yellow | Orange |
| 4 | Blue | Green | Yellow | Orange |
| 5 | Blue | Green | Yellow | Orange |
| 6 | Blue | Green | Orange | Orange |
| 7 | Blue | Blue | Yellow | Orange |
| 8 | Blue | Blue | Yellow | Yellow |
| 9 | Blue | Green | Yellow | Orange |
| 10 | Blue | Green | Yellow | Orange |
| 11 | Blue | Green | Yellow | Orange |
| 12 | Blue | Green | Yellow | Orange |
| 13 | Blue | Green | Orange | Orange |
| 14 | Blue | Blue | Yellow | Orange |
| 15 | Blue | Green | Yellow | Orange |
| Accuracy | 100% | 80.00% | 80.00% | 86.67% |

The accuracy of the detection was always 80% or above.

**Conclusion:** Ring detection reliable.

**Action:** This report will be sent to the software team and hardware team to make necessary changes.

**Distribution:** Software development, Project Management

Test 9: Odometer

**Date:** 5/11/18
**Tester:** Ashish
**Author:** Ashish
**Hardware Version**: 1.1
**Software Version:** N/A

**Goal:** To determine the reliability of the odometer.

**Procedure:** Set the robot at (0,0) and run the square driver from lab 2. Measure the resulting x and y distances with respect to the starting position of the robot. Compute the Euclidean error, mean value and standard deviation

**Expected Results:** The Euclidean error should be smaller than 2cm.

**Test Report:** The test was performed 10 times and the results are shown in the table below:

| | Xs | Ys | X | Y | error |
|---|---|---|---|---|---|
| Run 1 | -1 | -0.3 | -0.1 | -0.21 | 0.904489 |
| Run 2 | -0.6 | -0.9 | -0.12 | -0.65 | 0.541202 |
| Run 3 | 0.4 | 1 | 0.914 | -0.43 | 1.519571 |
| Run 4 | 0.7 | -1.2 | 0.13 | 0.374 | 1.67403 |
| Run 5 | 1.6 | 1 | 0.103 | 0.332 | 1.639278 |
| Run 6 | 0.3 | 1.2 | 0.169 | 0.09 | 1.117703 |
| Run 7 | -0.6 | -0.7 | 0.192 | -0.63 | 0.795087 |
| Run 8 | -2.8 | 3.2 | -0.09 | -0.46 | 4.554086 |
| Run 9 | -0.5 | 0.3 | -0.35 | 0.23 | 0.165529 |
| Run 10 | 0.6 | -0.4 | 0.48 | -0.246 | 0.195233 |
| Mean | | | 0.1328 | -0.16 | 1.310621 |
| Standard deviation | | | 0.337249 | 0.370893 | 1.200794 |

The mean values and Euclidean error were all below 2 cm.

**Conclusion:** The odometer is reliable in the current hardware configuration

**Action:** This report will be sent to the software team to make necessary changes.

**Distribution:** Software development, Project management