ECSE 211 - Design Principles and Methods

Testing Document

GROUP 11
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Abstract

This document will outline the tests in preparation for the final competition. The purpose of this document is to outline the tests done, show the recorded values for each test and present the evaluations for each test result.

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1 EDIT HISTORY

- Monday February 27th:
  - Ian Smith: initial set-up of document and start of Test 1 (section 2.1)
- Week of Feb 27 - 5th:
  - Ian Smith: Completion of Test 1 (section 2.1)
- Wednesday March 8th
  - Alex Lam: General formatting
- Saturday March 12th
  - Ian Smith: Ultrasonic and Light sensors testing results (section 2)
- Thursday March 16th:
  - Durham Abric: Added test data, remarks, formatting (section 6.1.1)
- Thursday March 16th:
  - Ian Smith: Added Testing data for Localization and testing description for sections 2.2, 2.3 and 3.1.

2 Parts Testing

2.1 Motors

Test 1:

This test was done on February 27, 2017 by Ian Smith.
8 Motors are being tested. 4 NXT Motors and 4 EV3 Motors.

Testing will be done by having each motor timed for a rotation of 360 degrees at a fixed velocity. 5 trials will be done for each motor and then the mean will be calculated. The mean will be used to determine which motors will be used. All measured and calculated values are in seconds (s).

The Mean is: $\mu = \frac{1}{N}\sum_{i=1}^{N} \Delta X$;

Where:

- N: number of trials
- X: data sample

Table 1: Motor Times per revolution 1 - 4

Trial	Motor 1(s)	Motor2 (s)	Motor 3 (s)	Motor 4 (s)
1	2.62	2.64	2.65	2.72
2	2.54	2.62	2.65	2.76
3	2.94	2.56	2.53	2.56
4	2.48	2.68	2.64	2.74
5	2.58	2.57	2.68	2.60

- Motor 1: $\mu = 2.63$ s
- Motor2: $\mu = 2.61$ s
- Motor 3: $\mu = 2.63$ s
- Motor 4: $\mu = 2.68$ s

Table 2: Motor times per Revolution 5 - 8

Trial	Motor 5 (s)	Motor 6 (s)	Motor 7 (s)	Motor 8 (s)
1	2.54	2.59	2.51	2.54
2	2.50	2.60	2.60	2.49
3	2.55	2.63	2.58	2.69
4	2.56	2.60	2.59	2.55
5	2.56	2.68	2.53	2.49

- Motor 5: $\mu = 2.54$ s
- Motor 6: $\mu = 2.62$ s
- Motor 7: $\mu = 2.56$ s
- Motor 8: $\mu = 2.55$ s

Motors 5, 7 and 8 will be used for the project based on the results. These motors will be tested again at each milestone.
Sources of Error: Incomplete definition - The measurement for the rotations are not defined. The reaction time of the person controlling the stopwatch needs to be taken into consideration.

2.2 Ultrasonic Sensor

This section will cover the accuracy of the ultrasonic sensors. The sensors will be place a known distance away from a wall and the distance shown on the brick will be recorded. This test was done on March 12, 2017. Standard Deviation: $\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$;

The Mean is: $\mu = \frac{1}{N}\sum_{i=1}^{N}\Delta X$;

Where:

- N: number of trials
- X: data sample

Table 1: Ultrasonic Sensor Readings

Trial	Distance (cm)	Sensor 1 (cm)	Sensor 2 (cm)	Sensor 3 (cm)
1	30.48	30.45	30.84	29.81
2	60.96	61.80	61.42	62.22
3	91.44	90.74	92.10	92.30
4	121.92	122.71	122.75	121.72

This table shows the distances the ultrasonic sensors were placed away from the wall and the readings that appeared on the EV3 brick.

Table 2: Ultrasonic Sensor Error

Trial	Sensor 1 Error (cm)	Sensor 2 Error (cm)	Sensor 3 Error (cm)
1	0.03	-0.36	0.67
2	-0.84	-0.46	-1.26
3	0.70	-0.66	-0.86
4	-0.79	-0.83	0.20

This table shows the error calculated from the first table. The Mean and Standard Deviations are shown below:

- Sensor 1: μ = -0.225 cm
- Sensor 2: μ = -0.5775 cm
- Sensor 3: μ = -0.3125 cm
- Sensor 1: σ = 0.64 cm
- Sensor 2: σ = 0.18 cm
- Sensor 3: σ = 0.78 cm

2.3 Light Sensor

The light sensors will be tested using the Red test function found on the EV3 brick. We will be testing the accuracy of the light sensors by recording the values displayed on the EV3 brick while the sensor is over a tile and a black line. This test was done on March 12, 2017. The Mean is: $\mu = \frac{1}{N}\sum_{i=1}^{N} \Delta X$;

Where:

- N: number of trials
- X: data sample

Table 1: Light Sensor Tiles

Trial	Sensor 1 (Red Values)	Sensor 2 (Red Values)
1	0.79	0.7
2	0.82	0.67
3	0.85	0.73
4	0.77	0.72
5	0.71	0.74

The table shows the readings gained from the light sensors when over a tile. The mean for each sensor follows:

- Sensor 1: $\mu = 0.79$
- Sensor 2: $\mu = 0.71$

Table 2: Light Sensor Black Lines

Trial	Sensor 1 (Red Values)	Sensor 2 (Red Values)
1	0.23	0.21
2	0.17	0.23
3	0.30	0.24
4	0.28	0.27
5	0.29	0.28

The table shows the readings gained from the light sensors when over a black line. The mean for each sensor follows:

- Sensor 1: $\mu = 0.25$
- Sensor 2: $\mu = 0.25$

3 Localization

3.1 Timing

This section covers how long the robot will take to localize in different positions. It will also include the accuracy of the positioning after the localization is complete. The Start θ will represent the starting position of the robot before localization. The End θ (Position) is the actual orientation of the robot after localization which was measured using a protractor. The End θ (Odo) is the θ valued showed on the screen of the robot which is calculated through the odometry code. Time is how long the robot took for it to end its localization. The Mean is: $\mu = \frac{1}{N}\sum_{i=1}^{N} \Delta X$;

Where:

- N: number of trials
- X: data sample

This test was done using a build of the robot which did not have the throwing arm or the two motors that are used to operate it. This test was done on March 13, 2017.

Table 1: Localization Timing and Orientation (Robot: Early Build)

Trial	Start θ - degrees	End θ(Position) - degrees	End θ(Odo) - degrees	Time - seconds
1	0	358	0.13	15.07
2	270	NA	NA	18.72
3	90	358	0.13	18.06
4	180	0	0.13	35.03
5	45	10	0.00	15.87
6	315	10	0.13	11.90
7	135	0	0.00	19.05
8	180	12	0.00	20.37
9	270	14	0.26	23.49
10	315	1	0.13	22.4
11	0	1	0.00	14.57
12	45	358	0.00	16.26
13	90	0	0.26	17.88
14	135	0	0.13	19.64
15	180	0	0.39	20.12
16	225	358	0.26	22.24
17	270	1	0.26	24.18
18	315	3	0.00	12.50

Trials 1 - 9 were done using an initial build of the localization code which was not tested. For trial 2 the robot could not localize and there were also cases where localization took more than 30 seconds which is does not meet our requirements. After trial 9 the localization code was adjusted by John Wu. Trials 10 - 18 were all successful and under the time constraints. The mean End θ (position) for trials 10 - 18 is 0.22

degrees. The mean Time for trials 10 - 18 is 18.87s.

This test was done using the final build of the robot which consists of 4 motors, 2 ultrasonic sensors and 2 light sensors. This test was done on March 20, 2017.

Table 1: Localization Timing and Orientation (Robot: Final Build)

Trial	Start θ - degrees	End θ(Position) - degrees	End θ(Odo) degrees	Time - seconds
1	0	2	0.13	14.85
2	45	1	0.00	16.36
3	90	0	0.13	18.20
4	135	5	0.13	20.41
5	180	4	0.26	21.30
6	225	3	0.13	22.91
7	270	1	0.00	26.08
8	315	3	0.00	12.87

Trials 1 - 8 were done using the final build of the localization code. The mean time for the localization to be completed is 19.12 seconds. All possible positions were within the competitions' time constraints. The mean Δ θ was 2.31 degrees which is within our threshold for the odometry correction method.

3.2 Odometer and Positioning

This section will cover tests done on the position of the robot on the field vs the odometer's recorded position.
This test was done using a build of the robot which did not have the throwing arm or the two motors that are used to operate it. This test was done on March 13, 2017.

Table 1: Placeholder

Trial	Start θ - degrees	End θ(Position) - degrees	End θ(Odo) degrees	Time - seconds
1	0	2	0.13	14.85
2	45	1	0.00	16.36
3	90	0	0.13	18.20
4	135	5	0.13	20.41
5	180	4	0.26	21.30
6	225	3	0.13	22.91
7	270	1	0.00	26.08
8	315	3	0.00	12.87

This test was done using the final build of the robot which consists of 4 motors, 2 ultrasonic sensors and 2 light sensors. This test was done on March 20, 2017.

Table 1: Placeholder

Trial	Start θ - degrees	End θ(Position) - degrees	End θ(Odo) degrees	Time - seconds
1	0	2	0.13	14.85
2	45	1	0.00	16.36
3	90	0	0.13	18.20
4	135	5	0.13	20.41
5	180	4	0.26	21.30
6	225	3	0.13	22.91
7	270	1	0.00	26.08
8	315	3	0.00	12.87

4 Navigation

; This section will cover the movement of the robot on the playing field. The robot's navigateTo method will be the focus of these tests. The robot will be told to travel to specific coordinates and the actual measurement will

4.1 Odometer

(Test movement on grid)

4.2 Square Driver

This test is used to ensure the recorded track length corresponds to the odometer's navigation.

4.3 Obstacle avoidance

(Is the robot able to avoid obstacles in different positions?)

5 Ball Retrieval

5.1 Getting to the ball dispenser

(Test navigation to the ball dispenser to ensure retrieval)

5.2 Picking up ball

(Test possible positions for the ball to be in for retrieval)

5.3 Placing ball onto launcher

(Test how successful the robot is at placing the ball in a ready to launch position)

6 Shooting ball

6.1 Distance

6.1.1 Initial Design Test

Purpose: To obtain proof of concept and/or calibrate the the throwing mechanism for the initial mechanical design.

Test Procedure: The throwing mechanism from the initial mechanical design (See Hardware Document) was detached from the robot and mounted firmly to the wooden-field surface, with the motor in contact with the surface. The mechanism was then tested with different motor accelerations and distance of rotations, recording the distance at which the ball first bounced for each trial.

Table 1: Throw Distance of Initial Design

Trial	Motor Acceleration (deg/s/s):	Motor Rotation (deg)	Distance Thrown (cm) (±5cm)
1	1500	75	50
2	1750	75	55
3	2000	75	50
4	2250	75	50
5	2500	75	60
6	2750	75	55
7	3000	75	55
8	3250	75	55
9	3500	75	55
10	3750	75	55
11	4000	75	55
12	1500	90	60
13	1750	90	65
14	2000	90	65
15	2250	90	65
16	2500	90	65
17	2750	90	70
18	3000	90	65
19	3250	90	65
20	3500	90	65
21	3750	90	70
22	4000	90	70
23	1500	105	65
24	1750	105	65

Trial	Motor Acceleration (deg/s/s):	Motor Rotation (deg)	Distance Thrown (cm) (±5cm)
25	2000	105	70
26	2250	105	70
27	2500	105	70
28	2750	105	70
29	3000	105	65
30	3250	105	75
31	3500	105	75
32	3750	105	75
33	4000	105	70
34	1500	120	60
35	1750	120	60
36	2000	120	60
37	2250	120	60
38	2500	120	60
39	2750	120	65
40	3000	120	65
41	3250	120	65
42	3500	120	65
43	3750	120	65
44	4000	120	65

Conclusions: Our current (March 12, 2017) ball launching mechanism doesn't have the ability to launch the ball the necessary distance to succeed in the competition. This appeared to be caused by a small range of motion (ROM) on which to do work on the ball. As a result, we have moved forward to design a new launching mechanism; it will have a larger ROM. We will use this test as a benchmark for further success/failure.

6.2 Release angle

6.2.1 Throwing arm test

Purpose: To calibrate the throwing arm for different target distances **Test procedure:** The target will stay in place and test throws will be performed starting at the 5 tile line and moving back until the 8 tile mark. In order to complete this test a special throwing arm program was developped which allowed for the angle of rotation of the motors to be modified in between throws which will allow for the ideal release angle to be found for each of the mentioned distances. At each one of the distance benchmarks, 7 trial throws will be performed for different release angles starting at an angle of 110 degrees and moving forward by increments of 5 degrees until 150 degrees or until the test is no longer deemed relevant (aka until the ideal release angle has been determined). The success or failure of each throw along with the bettery level of the brick at the time of the trials will be recorded in seperate tables for every distance.

Table 1: 5 Tiles

Angles	Success					
110	Yes(7.6)	Yes(7.6)	No(7.6)	Yes(7.5)	-	-
120	No (7.6)	-	-	-	-	-
125	-	-	-	-	-	-
130	-	-	-	-	-	-
135	-	-	-	-	-	-
140	-	-	-	-	-	-
145	-	-	-	-	-	-
150	-	-	-	-	-	-

Table 2: 6 Tiles

Angles	Success					
110	-	-	-	-	-	-
120	-	-	-	-	-	-
125	-	-	-	-	-	-
130	-	-	-	-	-	-
135	-	-	-	-	-	-
140	-	-	-	-	-	-
145	-	-	-	-	-	-
150	-	-	-	-	-	-

Table 3: 7 Tiles

Angles	Success					
110	-	-	-	-	-	-
120	-	-	-	-	-	-
125	-	-	-	-	-	-
130	-	-	-	-	-	-
135	Yes(7.8)	Yes(7.8)	Yes(7.8)	Yes(7.8)	Yes(7.8)	Yes(7.8)
140	Yes(7.7)	Yes(7.7)	Yes(7.7)	Yes(7.7)	Yes(7.7)	Yes(7.7)
145	-	-	-	-	-	-
150	-	-	-	-	-	-

Table 4: 8 Tiles

Angles	Success					
110	-	-	-	-	-	-
120	-	-	-	-	-	-
125	-	-	-	-	-	-
130	-	-	-	-	-	-
135	No (7.6)	No(7.6)	-	-	-	-
140	Yes(7.6)	No(7.6)	Yes(7.6)	Yes(7.6)	Yes(7.6)	Yes(7.5)
145	Yes(7.6)	No(7.6)	Yes(7.5)	Yes(7.5)	Yes(7.5)	No(7.5)
150	-	-	-	-	-	-

6.3 Bounce

(Test the amount of times the ball bounces within the green zone before going to the goal)

6.4 Scoring

(Test shots from different angles and distances

7 Defense

7.1 Navigation

(Gets to the defense zone)

7.2 Localization

(Same as before)

7.3 Blocking

(Test responsiveness of blocking arm)

8 GLOSSARY OF TERMS

- Requirements document: Separate document in which the requirements of the project are outlined and discussed in detail.
- Mindstorm EV3 kit: This is the hardware kit containing the majority of the hardware components to be used in this project.
- API: The Application program interface is a set of routines, protocols, and tools for building software applications
- Java Lejos API: The firmware used in order to allow Java code to be executed on the Mindstorm EV3 device.
- Noise: unwanted data reported by devices that causes error in performance