Scientific Experimentation and Evaluation

Assignment: 02

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26-April-2018

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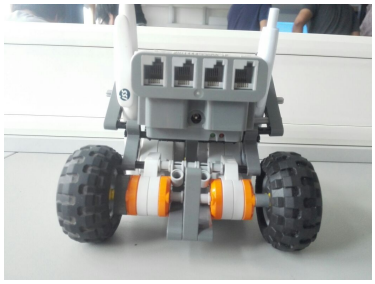
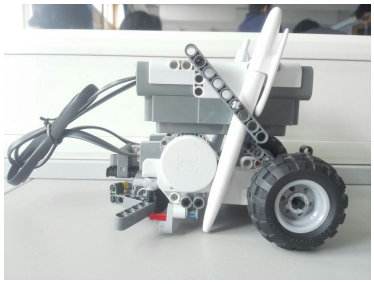
1 Relevant Aspects of Experiment

1.1 Design of Robot

- The robot has been designed with three wheels.
- Two of these are driving wheels and are connected to the motors, thus enabling a differential drive systems; and the third is a caster wheel at the back.
- Wheels are oriented as shown in the images below.



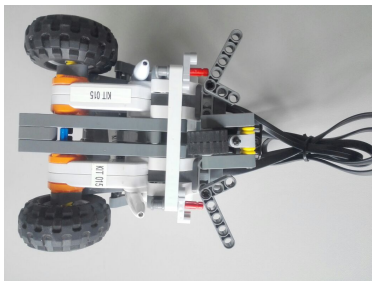
(a) Front View



(b) Right View

(c) Left View

(d) Top View



(e) Bottom View

Figure 1: Robot Design

- In addition, as shown above in the bottom view, it is ensured that the caster wheel does not rotate 360°.

1.2 Transformations

- Distance from pen axis to wheel axis = 5 cm
- Distance between the mid points of the two wheels (track width) = 11.5 cm
- WRITE FORMULA

1.3 Measurement of Start and Stop Positions

1.3.1 Measurement Instruments

- Distance:
  - We use a scale ruler to measure the distances.
  - In addition, we also utilize the grids on the paper which acts as our workspace and world coordinate systems.
  - Instrument Details:
    - 1 square of the grid paper equals 2.5×2.5 cm
    - The precision of the scale used is 1 mm.
- Angle:
  - A protractor is used as a measuring instrument for the angles.
  - Instrument Details:
    - Precision of the protractor used is 1°.

1.3.2 Measurement Procedure

- Two pens will be fixed near the two driving wheels.
- The starting position is where the two pens meets the x -axis, with the left pen lying on the origin (right pen at a distance of 8.3 cm from the origin).
- To measure the orientation of robot, the two points from these pens will be joined by drawing a line, which will be used to mark the pose of robot, with respect to the coordinate system defined.
- For each run, at the initial condition, it is ensured that orientation of rear caster wheel axle is parallel to the driving wheel axis.
- Measuring Position:
  - To get the position of the robot, we measure the distance of the two points from X and Y axis using a scale ruler.
  - These two readings are put in the transformation equation described above to get the actual position of the robot.
- Measuring Angles:

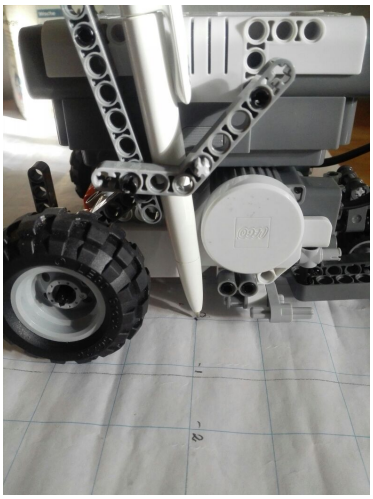


Figure 2: Staring Position

- The angular pose of the robot is the angle the X-axis makes with the normal to the line joining the two points.
- This angle is equal to the angle Y-axis makes with the line joining the two points. This can be verified using basic geometry, as shown in the image below.

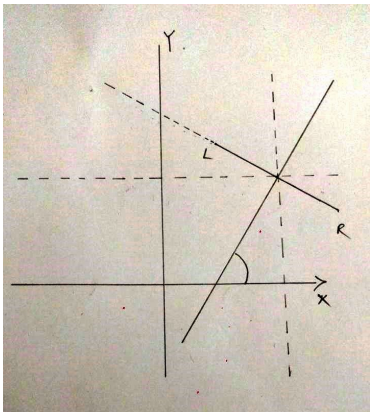


Figure 3: Measurement of angles

- We now measure the angle using a protractor.

1.4 Parameters used to drive the robot

- Constant angular and translational speed for a fixed time period to describe an arc to left.
- Constant translational speed and no angular speed for a fixed time period to describe a straight line.

- Constant angular and translational speed for a fixed time period to describe an arc to right.

1.5 Program used to drive the robot

- Using the Lego Mindstorms NXT 2.0 software, we created the scenarios for three run sequences.
- Straight Line:
  - Power: 50%
  - Duration: 3 Seconds
  - Steering Angle: 0 degrees
- Left Arc:
  - Power: 50%
  - Duration: 3 Seconds
  - Steering Angle: -45 degrees
- Right Arc:
  - Power: 50%
  - Duration: 3 Seconds
  - Steering Angle: 45 degrees
- The power percentage to wheel rpm has been calculated on the basis of readings found in [1]. It is observed that in the unloaded condition, 50% power results to around 80 rpm
- Diameter of wheels: 5.7 cm

1.6 Expected Problems and Performance

- Axis connecting the two pens might not be parallel to the wheel axle.
- Start position of each run may not be exactly similar owing to inaccurate positioning of the robot, this will result in lower precision.
- Pens may slip of move during the run, as such may not result in accurate positions, thus affecting the precision of our readings.
- The constant angular and translational speeds that we assume, may be inaccurate. The actual speed may differ and thus our estimate from the time will be inaccurate.
- The initial acceleration and final deceleration of the robot has not been considered in the experiments, resulting in low accuracy.
- In addition of the two previous points, slippage in the wheels and motors will also affect the accuracy of readings.

- The driven wheel will also result in the bot to drift and also decrease the distance it reaches.
- In addition, the calculation of expected position in each case is based on percentage of power applied to the motor and duration for which it is applied. However, this may result in an overestimate because of the following:
  - Actual power output may depend on the charge in batteries and the efficiency of motor.
  - Speed of the robot is calculated on the basis of this power output and the load on wheels, for calculation, we have approximated the motor rpm to a no-load condition. This is not true in the actual experiment.

2 Observations and Data

2.1 Readings

	X_L(cm)	Y_L(cm)	X_R(cm)	Y_R(cm)	Angle(degrees)
0	0	0	8.3	0	90

Table 1: Intial Position

	X_L (cm)	Y_L (cm)	X_R (cm)	Y_R (cm)	Theta (degrees)
0	0.2	52.2	8.4	52.1	89
1	2.0	52.4	10.3	52.0	87
2	1.6	52.4	9.9	52.0	88
3	1.2	52.3	9.5	52.0	88
4	0.4	52.3	8.7	52.2	89
5	-0.5	52.4	7.2	52.3	90
6	-1.5	52.4	6.7	52.4	90
7	1.5	52.5	9.7	52.1	87
8	0.2	52.5	8.4	52.4	89
9	0.2	52.5	8.3	52.5	88
10	0.5	52.3	8.8	52.0	88
11	1.0	52.3	9.2	51.9	88
12	0.4	52.3	8.6	52.3	89
13	-2.1	52.2	6.2	52.4	91
14	-1.0	52.6	7.3	52.6	90
15	-0.3	52.3	7.9	52.2	89
16	-0.2	52.5	8.0	52.3	89
17	0.4	52.3	8.6	52.2	89
18	0.7	52.5	8.9	52.2	88
19	1.0	52.5	9.2	52.2	88

Table 2: Straight Line Position

	X_L (cm)	Y_L (cm)	X_R (cm)	Y_R (cm)	Theta (degrees)
0	-19.7	35.0	-15.8	42.3	145
1	-19.3	35.5	-15.2	42.6	142
2	-19.6	35.4	-15.6	42.6	145
3	-18.1	35.5	-13.8	42.9	141
4	-19.5	35.2	-15.5	42.3	144
5	-20.0	34.9	-16.2	42.0	148
6	-20.2	34.7	-16.3	41.8	144
7	-17.5	36.5	-13.0	43.4	142
8	-18.6	35.7	-15.1	42.6	145
9	-19.2	35.6	-14.8	42.7	146
10	-19.3	35.3	-15.2	42.4	147
11	-18.5	35.6	-14.1	42.8	145
12	-20.1	34.7	-16.1	41.9	148
13	-19.5	35.2	-15.6	42.3	147
14	-19.8	34.6	-16.1	41.9	148
15	-18.7	35.6	-14.4	42.7	145
16	-19.4	35.0	-15.2	42.3	146
17	-19.5	34.5	-14.8	41.8	149
18	-19.3	35.3	-14.8	42.4	145
19	-19.5	34.1	-13.2	41.5	149

Table 3: Left Arc Position

	X_L (cm)	Y_L (cm)	X_R (cm)	Y_R (cm)	Theta (degrees)
0	23.7	42.2	27.5	35.0	33
1	22.4	43.2	26.5	36.1	34
2	22.7	42.6	26.9	35.5	34
3	23.2	42.5	27.3	35.2	34
4	21.5	43.7	25.8	36.7	35
5	20.3	43.5	25.0	36.7	39
6	22.6	43.0	26.7	36.0	40
7	23.1	42.7	27.2	35.5	34
8	24.2	42.1	28.1	34.8	33
9	22.9	43.0	27.0	35.8	34
10	23.5	42.3	27.5	35.1	33
11	25.5	41.0	29.2	34.1	30
12	22.8	42.7	26.9	35.6	34
13	24.2	42.2	28.1	34.9	32
14	22.4	42.6	26.5	35.5	34
15	23.4	42.1	27.4	34.9	33
16	24.4	42.1	28.2	34.7	32
17	24.5	42.2	28.2	34.9	32
18	22.9	42.8	27.0	35.7	33
19	24.4	42.1	28.2	34.7	31

Table 4: Right Arc Position

Detailed data is available in the file "Assignment01_data.ods"

2.2 Visualization

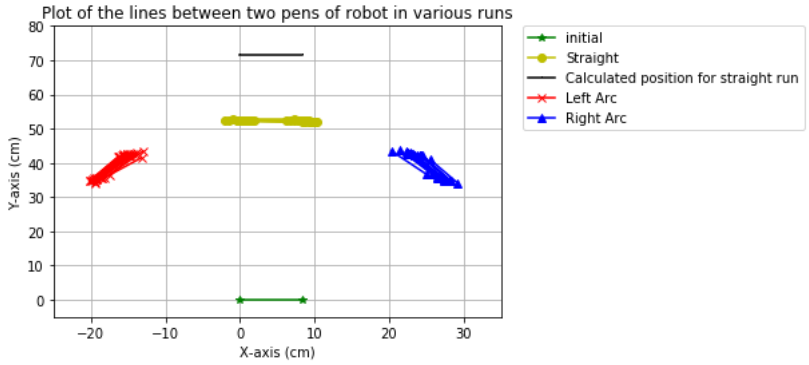


Figure 4: Plot of the lines between two pens of robot in various runs

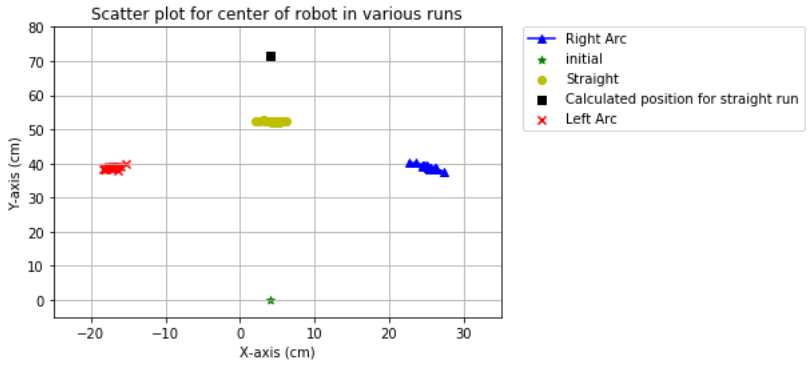


Figure 5: Scatter plot for center of robot in various runs

All the plots and code is available in the file "SEE_Experiment01_plots.ipynb"

3 Results

- Straight Run:
  - Mean X value: 52.3 cm
  - Mean Y value: 4.4 cm
  - Mean Angular value: 88.7 degrees
  - Standard Deviation in X value: 1.0 cm
  - Standard Deviation in Y value: 0.1 cm
  - Standard Deviation in Angular value: 1.0 degrees
  - Accuracy: 73 %

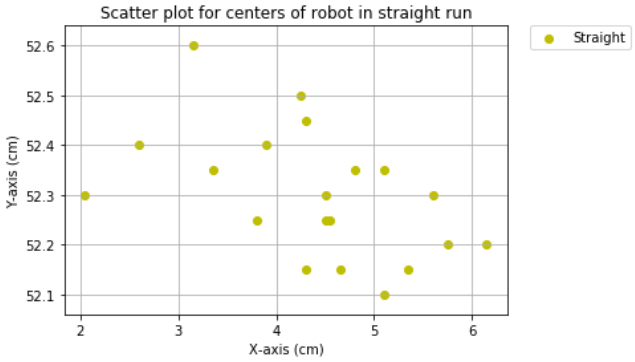


Figure 6: Scatter plot for centers of robot in Straight run

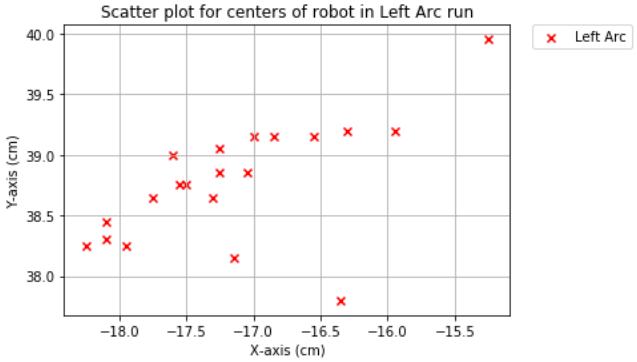


Figure 7: Scatter plot for centers of robot in Left Arc run

- Left Arc:
  - Mean X value: -17.2 cm
  - Mean Y value: 38.8 cm
  - Mean Angular value: 145.6 degrees
  - Standard Deviation in X value: 0.8 cm
  - Standard Deviation in Y value: 0.5 cm
  - Standard Deviation in Angular value: 2.3 degrees
- Right Arc :
  - Mean X value: 25.2 cm
  - Mean Y value: 39.0 cm
  - Mean Angular value: 33.7 degrees
  - Standard Deviation in X value: 1.0 cm
  - Standard Deviation in Y value: 0.6 cm
  - Standard Deviation in Angular value: 2.3 degrees

The details of calculations of these values is available in the file "SEE_Experiment01_plots.ipynb"

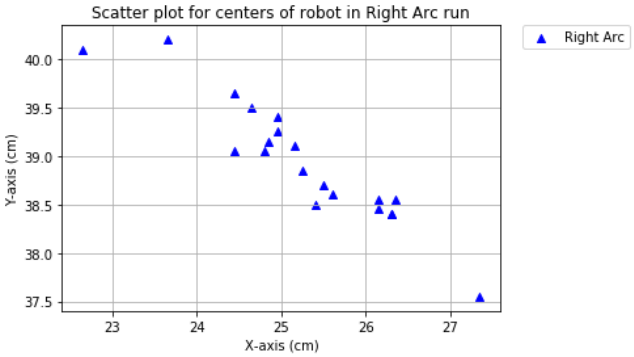


Figure 8: Scatter plot for centers of robot in Right Arc run

References

[1] Nxt motor internals. `http://www.philohome.com/nxtmotor/nxtmotor.htm`. Accessed: 2018-04-25.