Lab Report #2 – Odometry

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ECSE 211 – Design Principles and Methods

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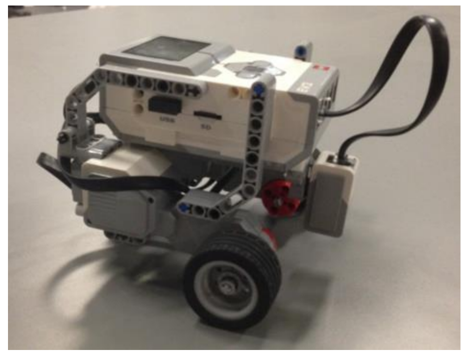
Design Evaluation

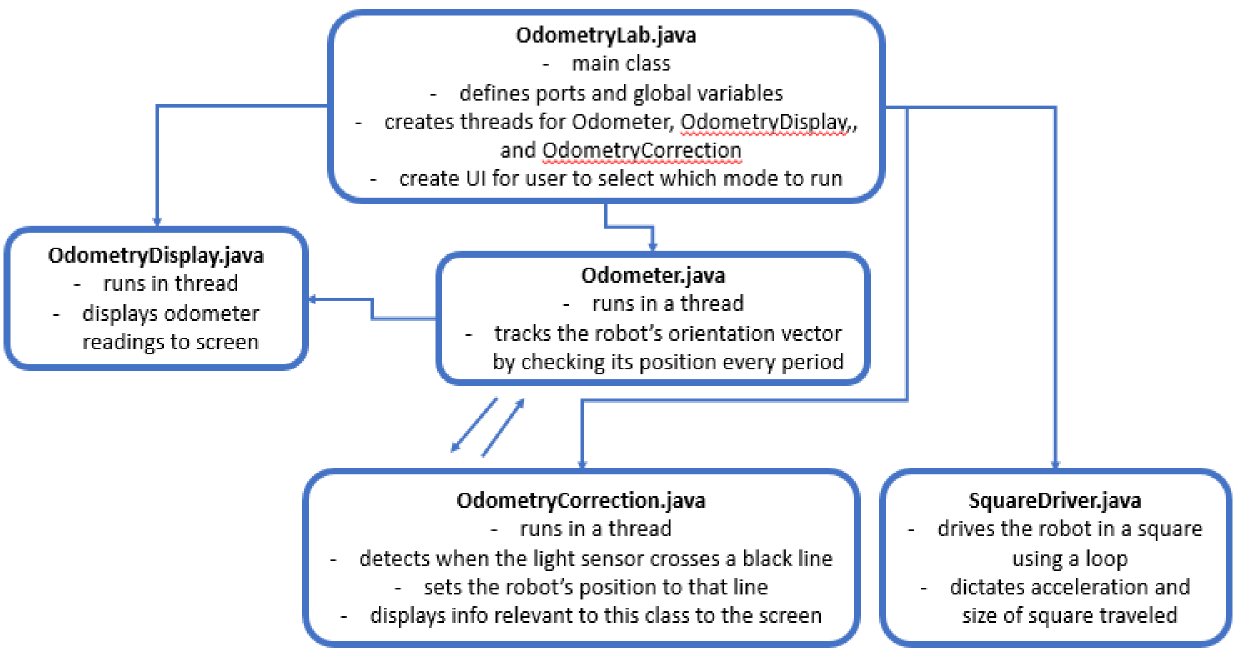
Hardware

A simple three-wheeled robot was created using two motors, two wheels, one ball bearing, one colour sensor, one EV3 brick, and various connecting pieces. The colour sensor was mounted to the front of the robot, below the brick but above the wheels, about two centimetres off the floor.



Software

The software structure was unchanged from the code provided.



Workflow (hours are a total of both lab partners)

1) Design robot based on given criteria (1 hour)
2) Fill in software framework code based on controller type and design criteria (8 hours)
3) Test design on grid floor. Identify errors in hardware and software that cause the robot to fail the design criteria, fix them, repeat (10 hours)
4) Demo project to TA (0.5 hours)
5) Lab report (3 hours)

Test Data

NOTE: In each trial, the robot started in the middle of the corner tile. X_F and Y_F are the measured finishing positions with respect to the origin – if they were the position relative to the starting position, the Euclidian error calculation would not make sense.

Odometer Test

Trial	Starting X	Starting Y	X_F	Y_F	X_odometer	Y_odometer
1	-15.24	-15.24	-13.93	-15.31	-15.13	-15.3
2	-15.24	-15.24	-16.57	-12.96	-15.13	-15.31
3	-15.24	-15.24	-16.98	-14.44	-15.12	-15.3
4	-15.24	-15.24	-16.99	-18.84	-15.13	-15.31
5	-15.24	-15.24	-13.42	-12.81	-15.13	-15.32
6	-15.24	-15.24	-17.56	-18	-15.12	-15.31
7	-15.24	-15.24	-16	-12.08	-15.13	-15.31
8	-15.24	-15.24	-15.03	-14.05	-15.13	-15.32
9	-15.24	-15.24	-18.74	-12.36	-15.14	-15.31
10	-15.24	-15.24	-18.08	-13.54	-15.13	-15.31

Odometer Correction Test

Trial	Starting X	Starting Y	X_F	Y_F	X_odometer	Y_odometer
1	-15.24	-15.24	-17.27	-18.44	-16.49	-18.08
2	-15.24	-15.24	-16.01	-18.8	-16.4	-18
3	-15.24	-15.24	-15.57	-11.22	-16.45	-18.1
4	-15.24	-15.24	-14.46	-10.81	-16.42	-18.09
5	-15.24	-15.24	-14.12	-10.79	-16.47	-18.06
6	-15.24	-15.24	-11.72	-13.85	-16.46	-18.1
7	-15.24	-15.24	-18.94	-17.11	-16.49	-18.07
8	-15.24	-15.24	-18.3	-18.58	-16.41	-18.04
9	-15.24	-15.24	-19.11	-14.3	-16.48	-18.02
10	-15.24	-15.24	-17.76	-10.86	-16.49	-18.03

Test Analysis

Odometer Test

Trial	Euclidean Error (ϵ)		Mean Error		Standard Deviation
1	1.200041666		2.937789601	**X**	0.005676462
2	2.75610232			**Y**	0.006666667
3	2.049194964			**ϵ**	1.134035203
4	3.990050125				
5	3.03713681				
6	3.631762657				
7	3.345115843				
8	1.273930924				
9	4.654299088				
10	3.440261618				

Odometer Correction Test

Trial	Euclidean Error (ϵ)		Mean Error		Standard Deviation
1	0.859069264		4.666545939	**X**	0.034705107
2	0.89			**Y**	0.035103023
3	6.93605075			**ϵ**	2.832015183
4	7.53923073				
5	7.640379572				
6	6.366325471				
7	2.631368465				
8	1.96562967				
9	4.555798503				
10	7.281606965				

The standard deviation of the odometer's X and Y position in the trials without correction is very low. This is because the odometer is never adjusted during the trial, meaning the odometer reading only varies by .01cm due to the small error margin in the motors' revolution counters.

The standard deviation of the odometer's X and Y position in the trials with correction is one order of magnitude higher because the odometer is corrected during the trial. The colour sensor detects the lines at slightly different times in each trial, and each trial is started at a slightly different position and angle (since the robot is placed down by hand), so the correction comes through to the odometer at slightly different times. This means that the robot travels a slightly different distance after the last correction in each direction in each trial, changing the odometer's final reading.

The standard deviation of the error in the uncorrected trials is lower than that of the corrected trials, for similar reasons. The sources of error for the corrected trials are the initial placement of the robot, the slip between the wheels and the floor, the measurement of wheel radius and wheel axle width, the compression of the wheels, and the flex of the wheel axle. The corrected trials share all those sources of error in addition to the error of the colour sensor reading, (i.e. how far across the line the sensor is when it detects the line).

The Y position is last corrected when the robot has three and a half squares to travel and two 90^o turns to make. The X position is last corrected when the robot has half a square to travel and one 90^o turn to make. Therefore, the error in the X position should be smaller for the corrected design because the robot has less distance to travel, and therefore less time to incur error, after the last X position correction.

Observations and Conclusions

The uncorrected odometer's error is not tolerable for longer distances. On a 15-by-15 grid, the robot would incur roughly 5 times the error in X_F and Y_F as a 3-by-3 grid because the sources of error would be the same and the robot has more distance to travel off-course. However, the measurement of the odometer at the end of the trial would *not* incur more error, because the only error occurs with the sensors' reading of the motor position at the end of the trial. Therefore, the Euclidian error would not scale by a factor of 5 – it is estimated that it would increase from ~3 to ~12, a factor of 4.

For the uncorrected odometer, the error is not expected to scale linearly with travel distance for the reasons stated above – the error in actual position would increase, but the error in odometer reading would not increase.

For the corrected odometer, the error is not expected to scale linear with travel distance, but for an entirely different reason. The correction of the odometer only holds when the robot is within the square it is intended to be. Once the robot crosses a "side" line (e.g. it is travelling in the Y direction but crosses an X direction gridline), its corrections will be made in the wrong coordinate and the error will increase exponentially.

Further Improvements

The slip of the robot's wheels occurs mostly during the start of the robot's movement after each turn, so slip can be reduced by making the motors' acceleration more gradual. Our motors' acceleration was set to a value of 500 (as opposed to 3000 in the code provided), but even lower acceleration values would further reduce slip.

The two light sensors would be placed as wide apart as possible (but not so far as to make the robot wider than one grid space), and at the same distance forward on the robot, such that if the robot crossed a grid line at exactly 90^o, the light sensors would detect the grid line at the same time. When one light sensor detects a line, the distance traveled would be tracked via wheel rotations until the other sensor detected the line. Then, the true angle of travel could be calculated based on the triangle in Figure 1, and the odometer could be adjusted accordingly.

The light sensor would be placed in any location on the robot that could make an accurate color reading of the floor. When the sensor detects

a grid line, the distance traveled would be tracked via wheel rotations until the sensor detected another grid line. The true angle of travel could be calculated based on the triangle in Figure 2, and the odometer could be adjusted accordingly.

$$\tan(\emptyset) = \frac{y}{x}$$

$$\emptyset = \tan^{-1}\frac{30.48}{x}$$

$$\theta = 90^o - \emptyset$$

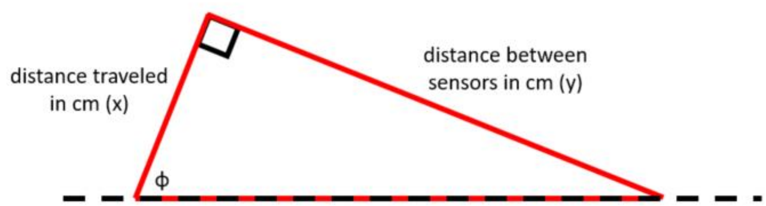


Figure 1 – two-sensor angle correction

$$\cos(\theta) = \frac{30.48}{x}$$

$$\theta = \cos^{-1}\frac{30.48}{x}$$

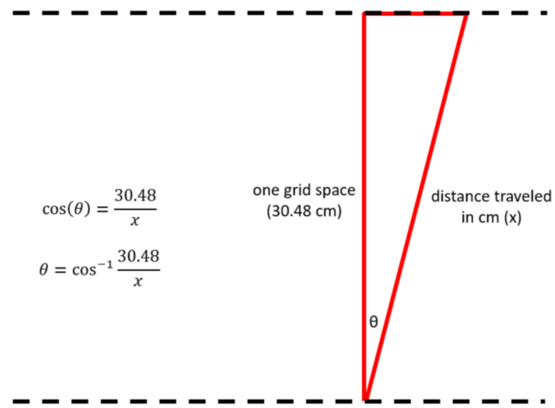


Figure 2 – one-sensor angle correction