Scientific Experimentation and Evaluation

Assignment 3

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Task Description

Our **task** is defined as: *Constructing a LEGO NxT differential drive robot and manually measure the observable pose variation for three different velocity motions.* The goal of this experiment is to observe the variation on the manual measured poses and look at the error distributions.

The layout of this experiment consists on:

1. Five different curves movements are going to be measured: Straight line and 4 arcs (2 left and 2 right).
2. The Device Under Test is a LEGO NxT robot.
3. A third-part library for the software is previously defined.

Plan for the experiment is given below:

1. Define the measurement method (see below).
2. Code a good program which takes into consideration the provided restrictions.
3. Define the curves that must be done according to pre-defined library.
4. Store the information of the final poses.
5. Repeat twenty times every curve measurement.
6. Compute the information to get the error gaussian distribution.

Experiment setup

Device Under Test

The Device Under Test is a LEGO NxT robot, shown at figure 1.

Figure 1: LEGO Nxt Robot

Measured Value

The polar coordinate of the robot (distance to origin, and angle θ).

Measurement System

The measurement value (final pose) is acquired by a LEGO NxT robot which uses the libraries provided by leJOS framework for motion and a large cardboard sheet, light sensor and geometric representation to acquire data.

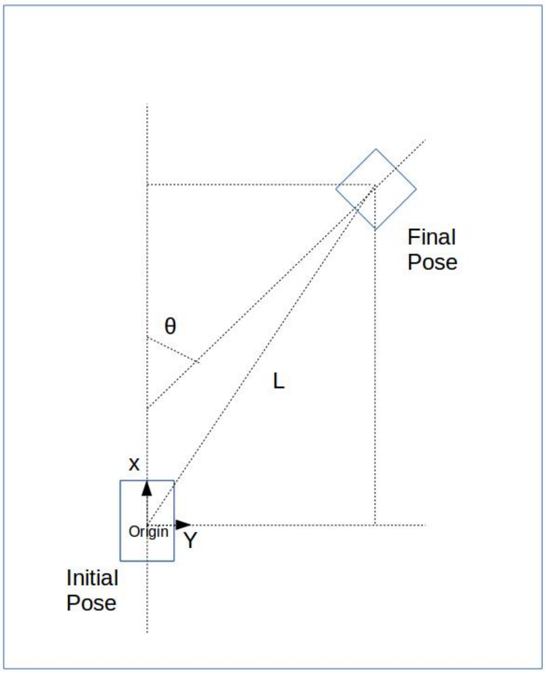
Measuring Method

To accomplish the task we have defined the experiment as explained in the picture.

The method description of image 2 is:

- A cardboard is used to mark the points of all the experiment.
- Two light sensors are used to mark the points in order to get the pose of the robot.
- Using LEGO light sensors initial pose is marked on the cardboard.
- A perpendicular axis which connects two original points is drawn as a reference.
- The origin is located between wheels so there distance from a sensor to the center must be measured.
- After the robot stops, a projection of the line is drawn between the two measured points pointed by the sensors.

Figure 2: Experiment Description



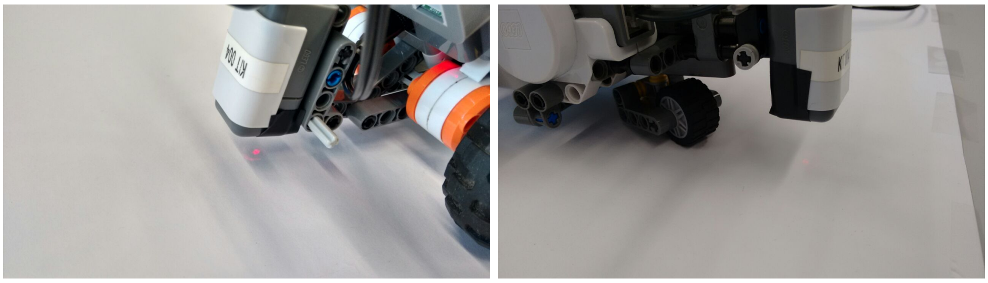
- The angle will be measured between the reference axis and the projected line.
- From the final marks, the new center is calculating extracting distance from initial marker to center along the projected line.
- Linear distance comes from the distance between measured center the and origin.
- For every repetition the initial pose must fit the original pose markers.
- After 5 repetitions, erase marks in order to get better measurements.

The Measurement facilities include:

- One cardboard.
- Two light sensors.
- A pen.
- A protractor.
- A rule.

The used light markers use is shown at image 3.

Figure 3: LEGO Nxt Robot Light Markers



What difficulties are expected?

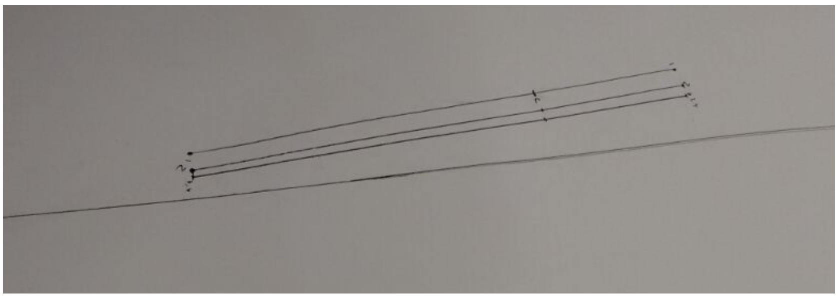
In order to accomplish the current task, we found the following constraints:

- The manual measurement will add errors to the measurement result.
- The precision of the instruments will affect the gaussian distribution.

Experimental Observations

An example of the measurement process can be seen at figure 4, this example comes from the straight line experiment.

Figure 4: LEGO Nxt Robot Light Markers



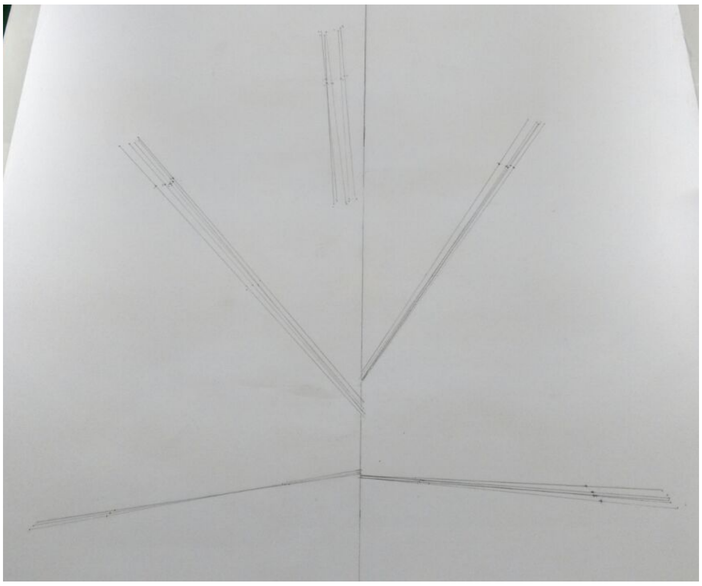
The right motor seems to be steeper as the left one, i.e. the straight line deviates to left (image 5). This effect is also observable at the other curves. The experiment trim shows us the last five measurements that were taken.

Precision and Accuracy

The precision of the experiment relies on the precision of the measurement facilities:

- For Distance Measurement: the rule was used which precision is 1 mm.

Figure 5: Experiments print



- For Angle Measurement: the protractor was used which precision is 1°.

Parameters used to drive the robot

Table 1: Parameters Used

	Arc radius	Angle	Distance	Track Width
Steep left arc	20	90		12
Steep right arc	20	90		12
Soft left arc		40	55	12
Soft right arc		40	55	12
Straight	40	90		12

Experiments Results

The experiments lead to the results provided at the attached file $first\_see\_data\_.ods$. In them, we can see that the protractor precision is not enough for this experiment due to the fact that many measurements fell somewhere between the scale so the measurement were round to the closer value. This round affects the accuracy of the experiment.

In addition of this, the design measurement system lacks of information in order to calculate the pose angle because with the distance from origin to robot final center these angle cannot be calculated. Therefore, the accuracy of the angle cannot be improved.

As consequence, a new measurement system is was designed to improve these results. The next section will provided the new measurement system.

Improved Measuring Method

For this new measuring method, the already provided robot structure at figure 3 and parameters at table 1 remain with no changes. In other words, the differential drive platform and light sensors are also considers for this method. However the number of repetitions were increased from twenty to forty.

For the new method, the next measurement facilities will be needed:

- One cardboard.
- Two light sensors.
- 10 pens of different color.
- A rule.

The modified method description of figure 6 is:

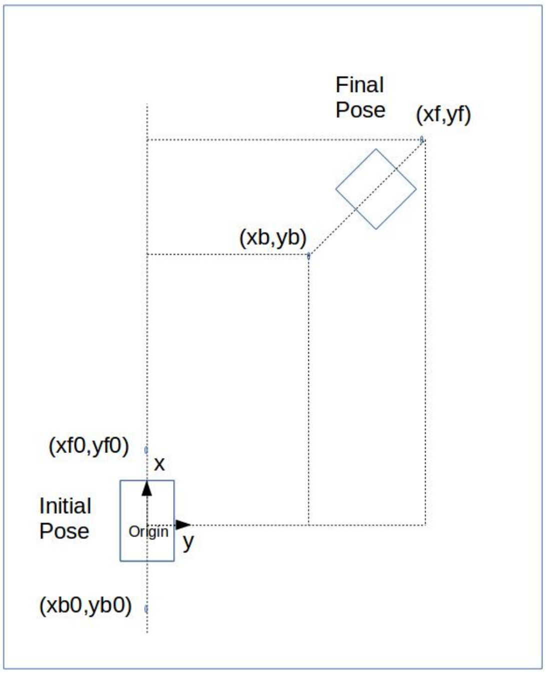


Figure 6: Improved Experiment Description

- A cardboard is used to mark the points of all the experiment.
- A world frame is drawn on the cardboard.
- Two light sensors are used to mark the points in order to get the pose of the robot.
- Using LEGO light sensors initial pose is marked on the cardboard with a point (one for front light sensor and other for backward light sensor).
- The program is run in the robot.
- When the robot stops, a new set of points(x,y) for each sensor are marked using the rule on the cardboard with a pen of different color.
- For every repetition the robot should be aligned according to the original points in order to warranty that the start pose is the same.
- After 10 repetitions (each one with different color) the points are measured and in order to not confuse the next round the points will be marked with a different shape.

- Having 40 repetitions of one curve, a different curve must be measured. In total, there are 5 different curves (200 repetitions).

Experiment Settings

A coordinate frame must be drawn at the cardboard (figure 7) A line was drawn every 10 cm for each axis.

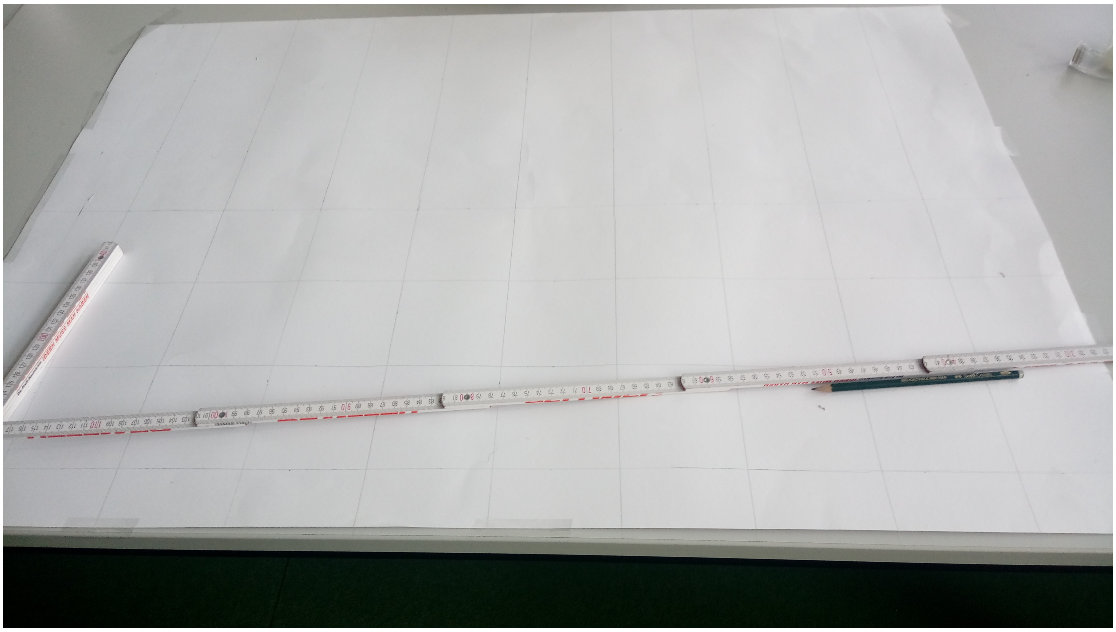


Figure 7: Coordinates Frames Draw Process

The complete grid is shown in the figure 8.
A world origin frame was selected on the grid (shown at figure 9).

Data Processing

The initial points from the sensors are shown at table 2. Those set of points define the initial pose of the robot, as it is seen the robot angle is of 0 ° from x axis.

We assume for this experiment that the robot center is in the middle of the robot therefore, the robot point center can be calculated as:

$$x_w i = xb_i + \left(\frac{xf_i - xb_i}{2} \right)$$

$$y_w i = yb_i + \left(\frac{yf_i - yb_i}{2} \right)$$

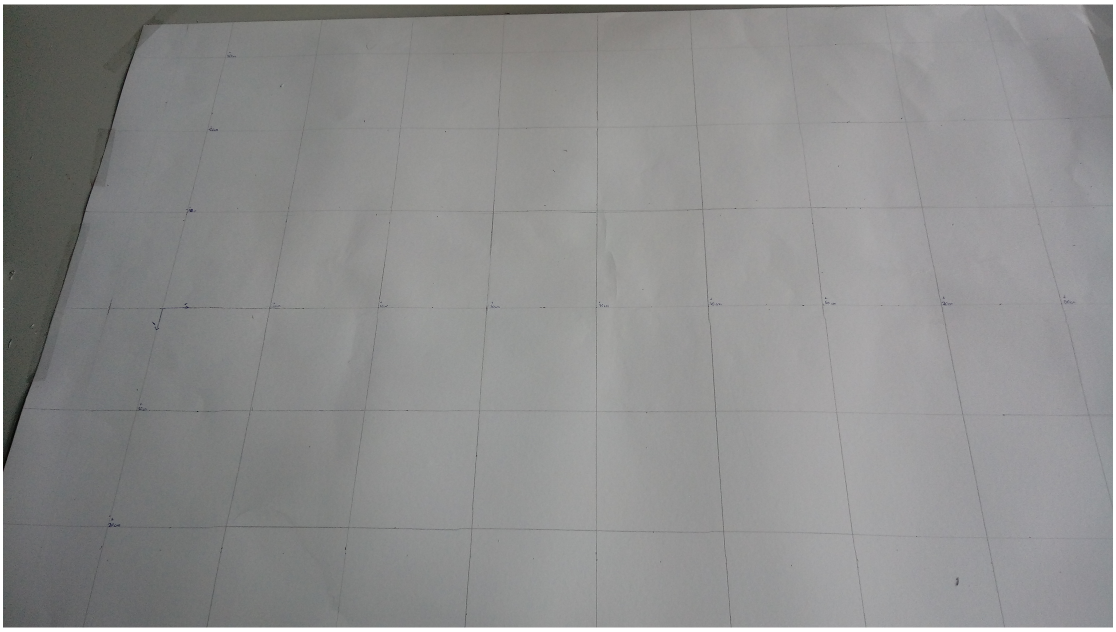


Figure 8: Complete Coordinates frames

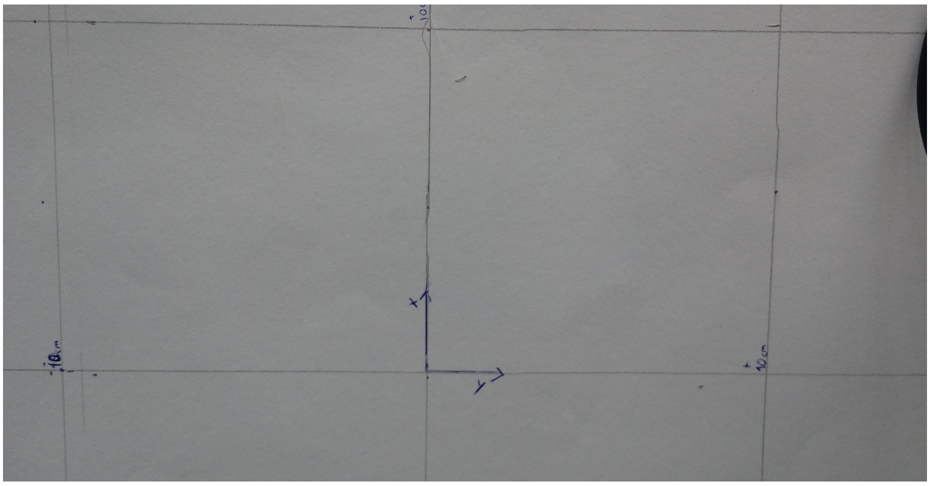


Figure 9: World Frame

Where i is the number of the experiment, f are front points, b are back ones and 0 are initial points .

This step is important because origin point are not in the origin of the coordinate

Table 2: Origin Laser Sensor Points

Initial Points		
Frame		World
	X	Y
Front Point	12	0
Back Point	-8.7	0

frame, therefore x_i and y_i must be translated .

$$\theta = tan^{-1}\left(\frac{y_w i}{x_w i}\right)$$

Experiments Results

The complete experiments results are at the attached file called *second_see_data_.ods*.

Final Robot poses

All measurements plot are shown at figure 10. Remembering that parameters from the curves are symmetric we can see that the straight line is slightly deviated from the perpendicular axis.

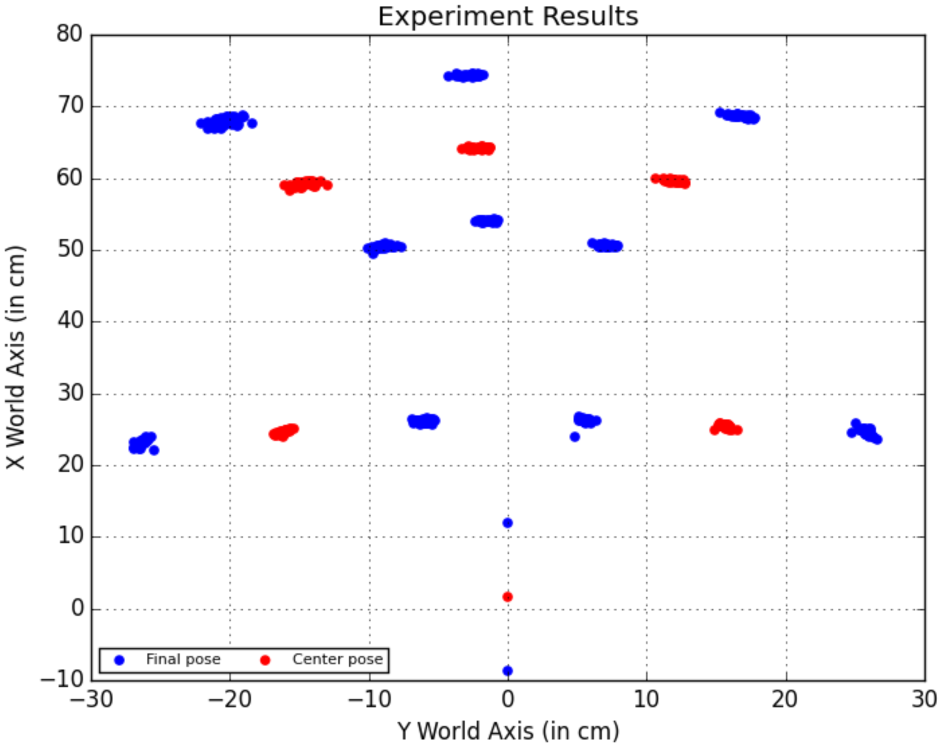


Figure 10: Robot stop position

Fitting Normal distribution to data

The robot center poses were calculated and PCA was performed on these poses to find the principal components.The data was projected along the principal components and we tried to fit a gaussaian to the projected data.The results are depicetd below.

Figure 11: Straight Line motion

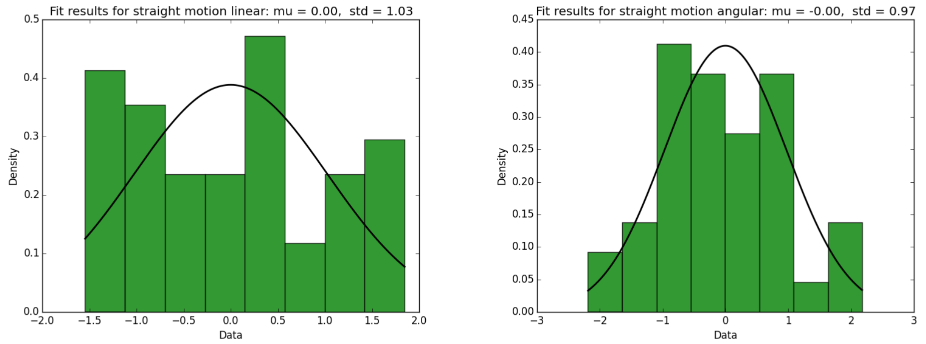


Figure 12: Slight Right motion

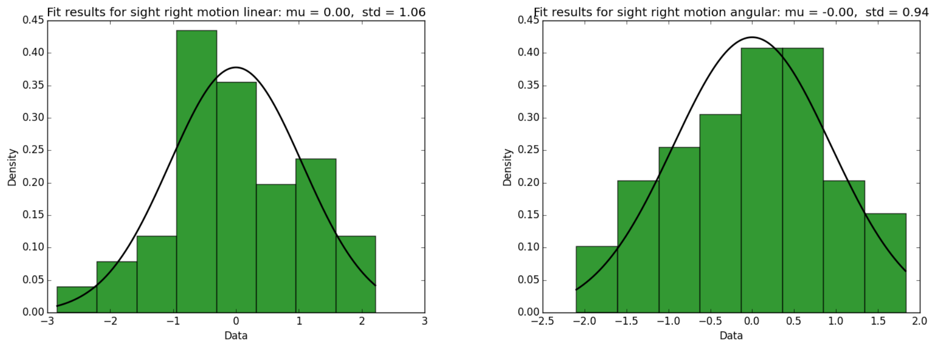


Figure 13: Slight Left motion

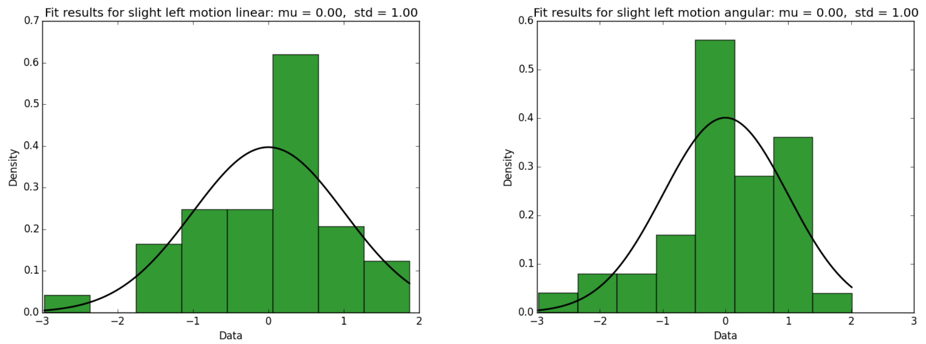


Figure 14: Steep Right motion

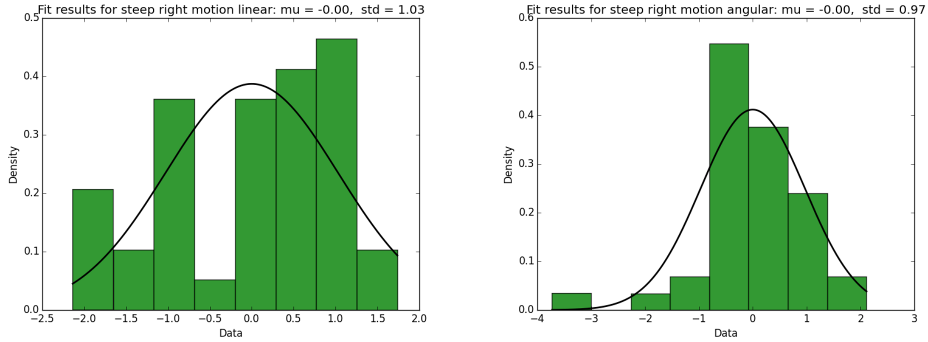


Figure 15: Steep Left motion