Lab 3 – Navigation (Group 51)

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Abstract

We designed a software system that allows a robot to move to an absolute location while avoiding obstacles.

1 Data

Repeated runs of the robot path in Figure 1 gave the data in Table 1. We used more precise measurements values used in the odometer from our last lab[1]; that made the error go down.

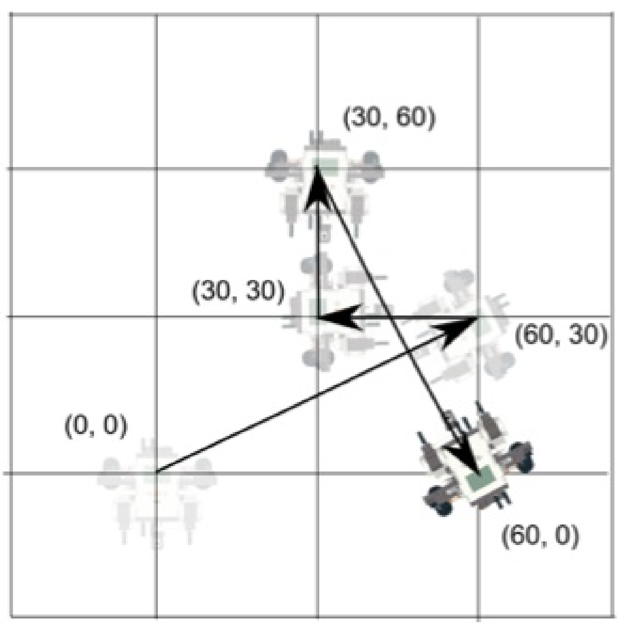

Figure 1: Robot navigation path in cm.[2]

2 Data Analysis

2.1 Discussion

The errors are part of the odometer. When we measured the odometer values more precisely, our errors dropped significantly. The navigator is just the software that reads from the odometer and decides where to go to minimise the error. It works by comparing a set minimum required error to the actual error and deciding whether that's good enough. We could reduce the error in the software, but that could create a condition where it's never good enough an it loops back incessantly.

2.2 Error Analysis

Calculate the differences in Equation 1–20.

$$\begin{aligned} d_{x,1} &= (0.0) - (-0.00) \\ &= 0.00 \end{aligned} \tag{1}$$

$$\begin{aligned} d_{y,1} &= (-60.0) - (-60.11) \\ &= 0.11 \end{aligned} \tag{2}$$

$$\begin{aligned} d_{x,2} &= (0.5) - (0.18) \\ &= 0.32 \end{aligned} \tag{3}$$

$$\begin{aligned} d_{y,2} &= (-59.5) - (-60.50) \\ &= 1.00 \end{aligned} \tag{4}$$

$$\begin{aligned} d_{x,3} &= (0.5) - (-0.10) \\ &= 0.60 \end{aligned} \tag{5}$$

$$\begin{aligned} d_{y,3} &= (-59.5) - (-60.50) \\ &= 1.00 \end{aligned} \tag{6}$$

$$\begin{aligned} d_{x,4} &= (0.5) - (0.06) \\ &= 0.44 \end{aligned} \tag{7}$$

$$\begin{aligned} d_{y,4} &= (-60.0) - (-60.31) \\ &= 0.31 \end{aligned} \tag{8}$$

actual		reported		error	
x (cm)	y (cm)	x (cm)	y (cm)	x (cm)	y (cm)
0.0	-60.0	-0.00	-60.11	0.0	0.1
0.5	-59.5	0.18	-60.50	0.3	1.0
0.5	-59.5	-0.10	-60.50	0.6	1.0
0.5	-60.0	0.06	-60.31	0.4	0.3
0.5	-60.5	0.11	-60.42	0.4	-0.1
0.0	-59.0	0.17	-60.51	-0.2	1.5
1.5	-61.0	0.06	-60.32	1.4	-0.7
1.5	-61.0	-0.04	-60.11	1.5	-0.9
1.0	-60.0	-0.09	-59.99	1.1	-0.0
0.5	-59.5	0.17	-60.50	0.3	1.0

Table 1: Reported error as read by the robot, and real error as read by a ruler and the difference between them. The difference, as (x, y), mean is $(0.60, 0.33)$, variance is $(0.33, 0.62)$, and the corrected sample standard deviation is $(0.58, 0.79)$.

$$\begin{aligned} d_{x,5} &= (0.5) - (0.11) \\ &= 0.39 \end{aligned} \tag{9}$$

$$\begin{aligned} d_{y,5} &= (-60.5) - (-60.42) \\ &= -0.08 \end{aligned} \tag{10}$$

$$\begin{aligned} d_{x,6} &= (0.0) - (0.17) \\ &= -0.17 \end{aligned} \tag{11}$$

$$\begin{aligned} d_{y,6} &= (-59.0) - (-60.51) \\ &= 1.51 \end{aligned} \tag{12}$$

$$\begin{aligned} d_{x,7} &= (1.5) - (0.06) \\ &= 1.44 \end{aligned} \tag{13}$$

$$\begin{aligned} d_{y,7} &= (-61.0) - (-60.32) \\ &= -0.68 \end{aligned} \tag{14}$$

$$\begin{aligned} d_{x,8} &= (1.5) - (-0.04) \\ &= 1.54 \end{aligned} \tag{15}$$

$$\begin{aligned} d_{y,8} &= (-61.0) - (-60.11) \\ &= -0.89 \end{aligned} \tag{16}$$

$$\begin{aligned} d_{x,9} &= (1.0) - (-0.09) \\ &= 1.09 \end{aligned} \tag{17}$$

$$\begin{aligned} d_{y,9} &= (-60.0) - (-59.99) \\ &= -0.01 \end{aligned} \tag{18}$$

$$\begin{aligned} d_{x,10} &= (0.5) - (0.17) \\ &= 0.33 \end{aligned} \tag{19}$$

$$\begin{aligned} d_{y,10} &= (-59.5) - (-60.50) \\ &= 1.00 \end{aligned} \tag{20}$$

Calculate the sum of the differences (Equation 1–20) in Equation 21–22.

$$\begin{aligned} \mathrm{sum}_x &= \sum_{i=1}^{10} d_{x,i} \\ &= (0.00)+ \\ &\quad (0.32)+ \\ &\quad (0.60)+ \\ &\quad (0.44)+ \\ &\quad (0.39)+ \\ &\quad (-0.17)+ \\ &\quad (1.44)+ \\ &\quad (1.54)+ \\ &\quad (1.09)+ \\ &\quad (0.33) \\ &= 5.98 \end{aligned} \tag{21}$$

$$
\begin{aligned}
\mathrm{sum}_y &= \sum_{i=1}^{10} d_{y,i} \\
&= (0.11)+ \\
&\quad (1.00)+ \\
&\quad (1.00)+ \\
&\quad (0.31)+ \\
&\quad (-0.08)+ \\
&\quad (1.51)+ \\
&\quad (-0.68)+ \\
&\quad (-0.89)+ \\
&\quad (-0.01)+ \\
&\quad (1.00) \\
&= 3.27 \qquad (22)
\end{aligned}
$$

Calculate the sum of the differences (Equation 1–20) squared in Equation 23–24.

$$
\begin{aligned}
\mathrm{ssq}_x &= \sum_{i=1}^{10} {d_{x,i}}^2 \\
&= (0.00)^2+ \\
&\quad (0.32)^2+ \\
&\quad (0.60)^2+ \\
&\quad (0.44)^2+ \\
&\quad (0.39)^2+ \\
&\quad (-0.17)^2+ \\
&\quad (1.44)^2+ \\
&\quad (1.54)^2+ \\
&\quad (1.09)^2+ \\
&\quad (0.33)^2 \\
&= 6.58 \qquad (23)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{ssq}_y &= \sum_{i=1}^{10} {d_{y,i}}^2 \\
&= (0.11)^2+ \\
&\quad (1.00)^2+ \\
&\quad (1.00)^2+ \\
&\quad (0.31)^2+ \\
&\quad (-0.08)^2+ \\
&\quad (1.51)^2+ \\
&\quad (-0.68)^2+ \\
&\quad (-0.89)^2+ \\
&\quad (-0.01)^2+ \\
&\quad (1.00)^2 \\
&= 6.65 \qquad (24)
\end{aligned}
$$

Calculate the mean from Equation 21–22 in Equation 25–26.

$$
\begin{aligned}
\mathrm{mean}_x &= \frac{\mathrm{sum}_x}{N} \\
&= \frac{5.98}{10} \\
&= 0.598000 \qquad (25) \\
\mathrm{mean}_y &= \frac{\mathrm{sum}_y}{N} \\
&= \frac{3.27}{10} \\
&= 0.327000 \qquad (26)
\end{aligned}
$$

Calculate the variance from Equation 21–22 and 23–24 in Equation 27–28.

$$
\begin{aligned}
{\sigma_x}^2 &= \frac{\mathrm{ssq}_x - \frac{{\mathrm{sum}_x}^2}{N}}{N-1} \\
&= \frac{6.58 - \frac{5.98^2}{10}}{10-1} \\
&= 0.333684 \qquad (27) \\
{\sigma_y}^2 &= \frac{\mathrm{ssq}_y - \frac{{\mathrm{sum}_y}^2}{N}}{N-1} \\
&= \frac{6.65 - \frac{3.27^2}{10}}{10-1} \\
&= 0.620001 \qquad (28)
\end{aligned}
$$

Calculate the corrected sample standard deviation from the variance (Equation 27–28) in Equation 29–30.

$$
\begin{aligned}
\sigma_x &= \sqrt{{\sigma_x}^2} \\
&= \sqrt{0.333684} \\
&= 0.577654 \qquad (29) \\
\sigma_y &= \sqrt{{\sigma_y}^2} \\
&= \sqrt{0.620001} \\
&= 0.787401 \qquad (30)
\end{aligned}
$$

3 Observations and Conclusion

We noticed experimentally that one actuator is not working, so we placed it on the top of our robot to hold the sensor. As such, the sensor can not move.

We tried `rotate` and `rotateTo` methods as seen in the last lab[1], but these inherently blocked output. The `setSpeed` method was more appropriate. `setSpeed` sets it to the absolute value of the speed; you then call `forward` or `backward` depending on the sign. This is not documented in the API.

"In three to four sentences, explain the operation of your controller(s) for navigation. How accurately does it move the robot to its destination? How quickly does it settle (stop oscillating) on its destination? You do not need to provide a quantitative analysis."

"How would increasing the speed of the robot affect the accuracy of your navigation? What is the main source of error in navigation (and odometry)?"

4 Further Improvements

"What steps can be taken to reduce the errors in navigation and odometry? In four (4) to six (6) sentences, Identify at least one hardware and one software solution, and provide an explanation as to why they would work."

References

[1] A. Bhandari-Young and N. Edelman, "Lab 2 odometry (group 51)," *McGill*, 2013.

[2] McGill, 304-211, *Lab 3: Navigation and Obstacle Avoidance.*