Lab 5 – Searching for Objects (Group 51)

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Abstract

Object detection is implemented using colour. Then, the robot localises in a set environment, searches for the foam object in a sea of wooden blocks, captures, and brings it to a set location in under five minutes.

1 Data and Analysis

1.1 Calibrating

1.2 Object detection

1. "Perform at least 10 trials of object recognition using an object other than the Styrofoam block and note the number of false positives.[1]"

   The other-object data is in Table 1. The arena is made entirely of wood, and we can successfully tell if the object is wood.

2. "Repeat the above step, but using the Styrofoam block each time, noting the total number of false negatives. Ideally both errors should be as small as possible.[1]"

   The styrofoam data is is Table 2. From the data can conclude that our algorithm is reliably able to differentiate the styrofoam from about 30 cm.

object	cm	recognises	percent
space		wood	50%
space		wood	50%
space		equal	
space		equal	50%
block	50	wood	51%
block	45	wood	53%
block	40	wood	57%
block	35	wood	68%
block	30	wood	74%
block	25	wood	82%
block	20	wood	81%
block	15	wood	88%
block	10	wood	95%
block	5	wood	98%
floor	50	wood	52%
floor	20	wood	84%
floor	10	wood	94%
side	50	wood	76%
side	20	wood	84%
side	10	wood	94%
side	5	wood	99%

Table 1: Space is empty space giving $(0, 0, 0)$ or very close; it has not been included. The differences can be explained by the orientation.

1.3 Searching for Objects

3. "Run through the search program at least 5 times, recording the average time taken to localize, to find a block, and then to travel to the destination. In the final competition, you must complete localization in less than 30 seconds. Also, estimate your localization and final destination errors for each trial.[1]"

   Table 3 is from Lab 4[2] which gives the errors on the localisation. Table 4 gives the time for each step and the total. It also gives an estimate on the error when reaching the end; this error is not normally distributed, it is a function of how many collisions the robot took.

object	cm	recognises	percent
styrofoam	90	wood	50%
styrofoam	90	styrofoam	50%
styrofoam	90	wood	50%
styrofoam	90	styrofoam	50%
styrofoam	90	wood	50%
styrofoam	90	wood	50%
styrofoam	80	styrofoam	50%
styrofoam	70	styrofoam	51%
styrofoam	60	styrofoam	54%
styrofoam	50	styrofoam	53%
styrofoam	40	styrofoam	59%
styrofoam	30	styrofoam	71%
styrofoam	20	styrofoam	84%
styrofoam	10	styrofoam	97%
styrofoam	5	styrofoam	98%

Table 2: Distance that the colour sensor can differentiate a styrofoam block.

θ_{start} (°)	θ_{final} (°)	θ_{reported} (°)	θ_{error} (cm)
45	359	1.8366	-2.8366
0	359	0.9664	-1.9664
315	0	1.6627	-1.6627
270	0	1.8364	-1.8364
225	359	1.4885	-2.4885
180	359	1.9662	-2.9662
135	0	1.8364	-1.8364
90	359	1.0112	-2.0112
345	0	1.0104	-1.0104
15	359	2.1846	-3.1846

Table 3: The error mean is $-2.18\,\text{cm}$, variance is $0.46\,\text{cm}^2$, and the corrected sample standard deviation is $0.67\,\text{cm}$.[2]

localising (s)	finding (s)	travelling (s)	total (s)	error (cm)
15	180	4	199	30
16	220	4	240	5
15	360	7	382	40
14	120	6	140	1
15	320	7	342	3
16	290	4	310	30

Table 4: The error mean is $18\,\text{cm}$, variance is $291\,\text{cm}^2$, and the corrected sample standard deviation is $17\,\text{cm}$.

2 Error Calculations

The localisation error in Table 3.[2]

Calculate the differences in Equation 1–10.

$$\begin{aligned} d_1 &= ((359) - (1.8366))_{360[-180,180]} \\ &= -2.8366 \end{aligned} \tag{1}$$

$$\begin{aligned} d_2 &= ((359) - (0.9664))_{360[-180,180]} \\ &= -1.9664 \end{aligned} \tag{2}$$

$$\begin{aligned} d_3 &= ((0) - (1.6627))_{360[-180,180]} \\ &= -1.6627 \end{aligned} \tag{3}$$

$$\begin{aligned} d_4 &= ((0) - (1.8364))_{360[-180,180]} \\ &= -1.8364 \end{aligned} \tag{4}$$

$$\begin{aligned} d_5 &= ((359) - (1.4885))_{360[-180,180]} \\ &= -2.4885 \end{aligned} \tag{5}$$

$$\begin{aligned} d_6 &= ((359) - (1.9662))_{360[-180,180]} \\ &= -2.9662 \end{aligned} \tag{6}$$

$$\begin{aligned} d_7 &= ((0) - (1.8364))_{360[-180,180]} \\ &= -1.8364 \end{aligned} \tag{7}$$

$$\begin{aligned} d_8 &= ((359) - (1.0112))_{360[-180,180]} \\ &= -2.0112 \end{aligned} \tag{8}$$

$$\begin{aligned} d_9 &= ((0) - (1.0104))_{360[-180,180]} \\ &= -1.0104 \end{aligned} \tag{9}$$

$$\begin{aligned} d_{10} &= ((359) - (2.1846))_{360[-180,180]} \\ &= -3.1846 \end{aligned} \tag{10}$$

Calculate the sum of the differences (Equation 1–10) in Equation 11.

$$\begin{aligned} \text{sum} &= \sum_{i=1}^{10} d_i \\ &= (-2.8366)+ \\ &\quad (-1.9664)+ \\ &\quad (-1.6627)+ \\ &\quad (-1.8364)+ \\ &\quad (-2.4885)+ \\ &\quad (-2.9662)+ \\ &\quad (-1.8364)+ \\ &\quad (-2.0112)+ \\ &\quad (-1.0104)+ \\ &\quad (-3.1846) \\ &= -21.7994 \end{aligned} \tag{11}$$

Calculate the sum of the differences (Equation 1–10) squared in Equation 12.

$$
\begin{aligned}
\text{ssq} &= \sum_{i=1}^{10} {d_i}^2 \\
&= (-2.84)^2 + \\
&\quad (-1.97)^2 + \\
&\quad (-1.66)^2 + \\
&\quad (-1.84)^2 + \\
&\quad (-2.49)^2 + \\
&\quad (-2.97)^2 + \\
&\quad (-1.84)^2 + \\
&\quad (-2.01)^2 + \\
&\quad (-1.01)^2 + \\
&\quad (-3.18)^2 \\
&= 51.62 \qquad (12)
\end{aligned}
$$

Calculate the mean from Equation 11 in Equation 13.

$$
\begin{aligned}
\text{mean} &= \frac{\text{sum}}{N} \\
&= \frac{-21.7994}{10} \\
&= -2.179940 \qquad (13)
\end{aligned}
$$

Calculate the variance from Equation 11 and 12 in Equation 14.

$$
\begin{aligned}
\sigma^2 &= \frac{\text{ssq} - \frac{\text{sum}^2}{N}}{N-1} \\
&= \frac{51.6208 - \frac{-21.7994^2}{10}}{10-1} \\
&= 0.455492 \qquad (14)
\end{aligned}
$$

Calculate the corrected sample standard deviation from the variance (Equation 14) in Equation 15.

$$
\begin{aligned}
\sigma &= \sqrt{\sigma^2} \\
&= \sqrt{0.455492} \\
&= 0.674902 \qquad (15)
\end{aligned}
$$

This is the error on Table 4.

Calculate the sum of the error in Equation 16.

$$
\begin{aligned}
\text{sum} &= \sum_{i=1}^{6} d_i \\
&= (30) + \\
&\quad (5) + \\
&\quad (40) + \\
&\quad (1) + \\
&\quad (3) + \\
&\quad (30) \\
&= 109 \qquad (16)
\end{aligned}
$$

Calculate the sum of the error squared in Equation 17.

$$
\begin{aligned}
\text{ssq} &= \sum_{i=1}^{6} {d_i}^2 \\
&= (30.00)^2 + \\
&\quad (5.00)^2 + \\
&\quad (40.00)^2 + \\
&\quad (1.00)^2 + \\
&\quad (3.00)^2 + \\
&\quad (30.00)^2 \\
&= 3435 \qquad (17)
\end{aligned}
$$

Calculate the mean from Equation 16 in Equation 18.

$$
\begin{aligned}
\text{mean} &= \frac{\text{sum}}{N} \\
&= \frac{109}{6} \\
&= 18.166667 \qquad (18)
\end{aligned}
$$

Calculate the variance from Equation 16 and 17 in Equation 19.

$$
\begin{aligned}
\sigma^2 &= \frac{\text{ssq} - \frac{\text{sum}^2}{N}}{N-1} \\
&= \frac{3435.0000 - \frac{109.0000^2}{6}}{6-1} \\
&= 290.966667 \qquad (19)
\end{aligned}
$$

Calculate the corrected sample standard deviation from the variance (Equation 19) in Equation 20.

$$\sigma = \sqrt{\sigma^2} = \sqrt{290.966667} = 17.057745 \tag{20}$$

3 Observations and Conclusions

We did a literature search and discovered that some varient of Kalman filter is used almost exclusively for robot navigation; for example in [3]. We did not use this because of time constraints, our robot following a heuristic path. We implemented a PID-control class. We have a light sensor and a colour sensor, so we could implement odometer correction; however, we wanted our robot to go at all angles anywhere in the field. Odometer correction was not tested with this relaxed constraint.

1. "What differences, if any, did you observe in the behavior/performance of your earlier code (i.e. localization, odometry, navigation) when combined in a larger system? Explain any discrepancies. If it turns out that things worked out pretty much as expected, explain how the design of your code contributed."

   The behaviour of the system when the elements were stuck together was to randomly turn and go off in an unstable speed loop, no matter what the behaviour expected. This was caused by the co-ordinate system not being standard.

2. "How reliable was your object detection? What factors influence the reliability of object detection? Where would you expect your code to break down? What steps can you take to make detection more robust?"

   The object detection was very solid. We used a method that is $\mathcal{O}(2^{n-1})$, but n is constant and two (styrofoam and wood.) We normalise our colours to make it lighting-independent. We compare with experimental value for the different substances, and pick the closest Cartesian distance to normalised colour values.

   The normalisation projects the HSL values onto L = 0.5 so it isn't affected by natural light. The barycentric coordinates are the square of these values. We could have multiplied the eigenvalues by their relative sensitivities, but we didn't know them; the blue was suspected to be lower when we tested it.

   The comparison introduces an error since we are working in normalised spherical co-ordinates. It's monotonic, which is all we care about when comparing. The approximate error is maximally seen in Equation 21.

   $$\int_{x=0}^{\sqrt{2}} \left(\sqrt{1-y^2} - (1-y)\right) dy \approx 0.19 \tag{21}$$

   We could try turning the flood light on while determining colour.

3. "What aspect of this lab did you find most difficult? What aspect of this lab did you find most surprising or unexpected?"

   The transferring of the code of lab 1–4[4, 5, 6, 2] to the new design. A lot of stuff just didn't work. This was expected since the code that was provided didn't use a standard coordinate system[7]. The mechanical planning of the robot was fun.

4 Further Improvements

The colour detection was pretty good, but the software was buggy otherwise; this is expected to happen when multiple sources are merged. The capture system was simple and worked good.

References

[1] McGill, 304-211, *Lab 5: Searching for Objects.*

[2] A. Bhandari-Young and N. Edelman, "Lab 4 – localisation (group 51)," *McGill*, 2013.

[3] A. J. Davison, "Real-time simultaneous localisation and mapping with a single camera," in *Computer Vision, 2003. Proceedings. Ninth IEEE International Conference on*, pp. 1403–1410, IEEE, 2003.

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

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

[6] A. Bhandari-Young and N. Edelman, “Lab 3 navigation (group 51),” *McGill*, 2013.

[7] “Iso 80000-2:2009,” International Organization for Standardization, 2009.