ICCS Coursework 1

Binzhou Gu, Zhanrui Liang and Tak Hei Wong

28 February 2020

Contents

List of Figures

List of Tables

1 Introduction

The ability for an autonomous robot to perform depends not only on its morphology and software architecture, but also the parameters it operates on. In this report, we explore the impact of changing the parameter “sensor range” on the performance of a room circumnavigating robot. The sensor range of the rover specifies the target distance to maintain between the rover and its nearest sidewall, which helps the robot to navigate through the room.

As suggested by Brooks, (1991), sensors such as sonar sensors suffer from reactivity issues, and if the target distance is too short, the rover might not react on time resulting in a collision with its nearby wall. Motivating by this, we present the hypothesis: ”An increase in the sensor range would enhance the performance of the rover in circumnavigating the track, as the robot would have more reaction time”.

Our experimental results show that an increase in sensor range increases performance. Nevertheless, it would also lead to the rover missing the more detailed part of the track, and this side effect might not be desirable in real-life applications. We conclude that many other elements impacting the performance and hence the intelligence of a room circumnavigating robot, therefore the parameters that are specific to one environment might not be applicable in another.

2 Approach

Various set up of wall following robots have been explored in previous literature. For example, Ando and Yuta, (1995) configure their rover with 12 sonar rings, whereas Munasinghe, (2006) have found similar success with just one set of sonar sensors. Constrained by the hard ward available, we equipped our rover with one rotatable sonar sensor and two touch sensors.

We are adopting a wall following algorithm similar to that of Lee, (2014), but instead of a reflex agent system, we have implemented a subsumption architecture version of the algorithm. While our control software (Figure 2) has only two levels, it allows for more expandability if we wish to include more sensors in the future. The lower layer commands the rover to move forward and the top-level subsume the lower layer when the touch sensors detects an obstacle ahead. To test our hypothesis, we have created an enclosing track, it consist of four sidewalls and an obstacle is placed at the end of the track creating a concave area (Figure 1). We measure the performance of the robot by recording the time needed for it to complete one lap of the track, recorded the number of times it collides with the side walls. We tested six different sensor range, from 0.1 meters to 0.35 meters, testing for every 0.05 meters increments.

Based on our wall following algorithm, in the ideal scenario the rover should collide with the wall six times, each responsible for a turning point in the track (Figure 3). Nevertheless, the rover would collide with the wall more often when the target distance is too close because of the delay due to the robot’s reaction time.

To minimize inconsistency in our experiment, we have controlled for the lighting condition in the room, and to ensure our robot are above 80% charged before running each trial.

3 Results

The experimental results show that the average time decrease as the sensor range setting increase. For example, when the rover is configured with a target distance of 0.35m, it only takes an average time of 36.92 seconds, which is a 43% improvement compared to the robot with a target distance setting of 0.10m. Conducting an Analysis of variance (ANOVA) with 95% confidence interval, we have found that sensor range has a significant impact on the time needed for the rover to complete a trial of the trial, where the resulting p-value is 1.1×10^{-35}. Formally, we have to reject the null hypothesis where sensor range has no impact on the time taken by the robot.

Furthermore, the results show a decrease in the number of collisions as we increase the sensor range, where it ranges from 7.6 times to 3.1 times for the two extreme sensor ranges (0.10m and 0.35m respectively). An ANOVA also shows a p-value of 1.9×10^{-26}, again rejecting the null hypothesis where the number of collisions is independent from the sensor range setting.

Overall, the statistical result is consistent with our hypothesis where a decrease in sensor range improves the performance of a room circumnavigating robot.

4 Discussion

While the statistical results are consistent with our hypothesis, it reminds debatable whether our choice of performance indicator is appropriate. As shown in Figure 3, the rover should collide with the walls six times upon completing the track by design. However, we have noticed that as we increase our sensor range beyond 0.30m, the rover starts to skip some parts of the track resulting in less collision and a reduces in time. In other words, the increase in performance is traded with the robot's ability to explore more detailed part of the room, which in some application such as a autonomous vacuum robot, might not be desirable.

To better understand this problem, we conducted another set of trials in a larger room (Second Experiment Video). With the same sensor range setting, we have found that even the highest sensor range we tested previously, did not skip any part of the track. This result indicates that the optimal sensor range balancing performance and accuracy might be dependent to the environment tested.

By analysing the p-values from our statistical tests, we have found more evidence that our results lack external validity.The two near zero p-values indicate that the situation is near impossible under the null hypothesis (i.e. where the sensor range has no impact on the time needed and collision), but this is certainly not the case where the track is completely straight. Our subsumption architecture implies that the second level would never subsume the first layer when the track is completely straight and hence the sensor range should never matter. For this reason, we deduce that our results are only applicable to this particular track or tracks with similar properties.

One final observation we made is that other parameters also have impact on performance. The robot's reaction time depends also on the speed and turning speed, given the same sensor range, changing the turning speed might dramatically impact if the rover is able to complete the track without extra collisions.

Despite the flaws in our findings, our experimental results might be useful in real-life applications. An interesting analogy is drawn in Antoun and McKerrow, (2010), where a similar wall following robot is used to mimic the behaviour of a blind person navigating through a wall. One application of our wall following robot can be for determining the optimal distance to maintain for a blind person when navigating through a particular room.

5 Conclusion

In conclusion, our result shows that the rover with greater sensor range completes a circuit with less time and collisions. However, the more detailed part of the track are less likely to be explored with higher sensor range. By configuration the robot with different sensor range, and exploring with the speed setting, we can balance the trade of between speed and accuracy in exploration task.

6 Video and raw data

- Main Experiment video:

  https://www.youtube.com/watch?v=7r52bq4XhnE

  The video shows in order the experiment conducted with sensor range 0.1m,0.3m and 0.35m.

- Second Experiment Video (Robustness test):

  https://www.youtube.com/watch?v=CCJW0t_3gGU

- Raw data and statistical test results available in the attached DATA.xlsx file.

References

Ando, Y. and Yuta, S., 1995. Following a wall by an autonomous mobile robot with a sonar-ring. *Proceedings of 1995 ieee international conference on robotics and automation*. Vol. 3. IEEE, pp.2599–2606.

Antoun, S.M. and McKerrow, P.J., 2010. Mimicking a blind person navigating a corridor using a k-sonar with a mobile robot. *Proceedings of the 3rd international symposium on practical cognitive agents and robots*, pp.1–8.

Brooks, R.A., 1991. Intelligence without representation. *Artificial intelligence*, 47(1-3), pp.139–159.

Lee, 2014. Wall following robot [Online]. Available from: `https://iamzxlee.wordpress.com/2014/06/21/wall-following-robot/`.

Munasinghe, R., 2006. *Wall following robot* [Online]. University of Moratuwa. Available from: `http://www.ent.mrt.ac.lk/iml/projects/2006/2k6EN407P3/report.pdf`.

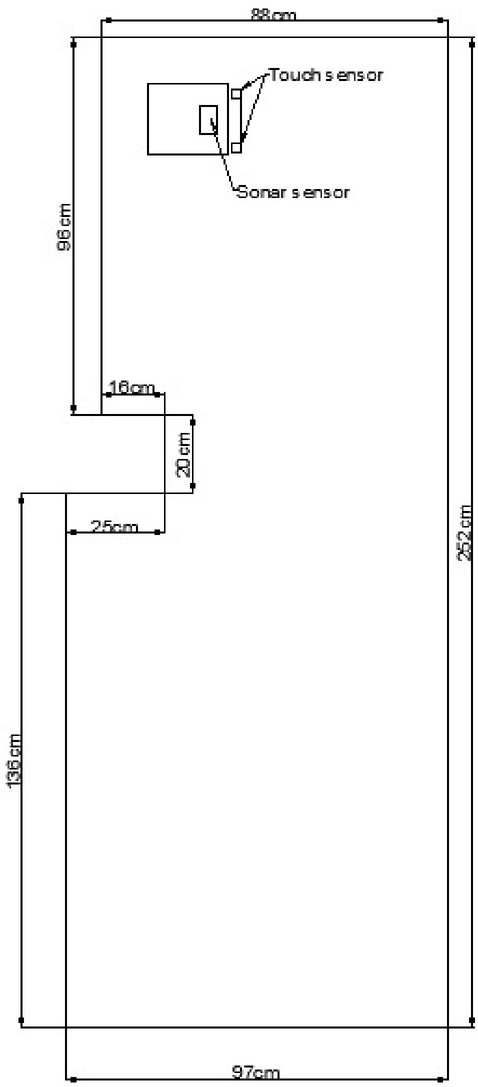

Figure 1: Track layout

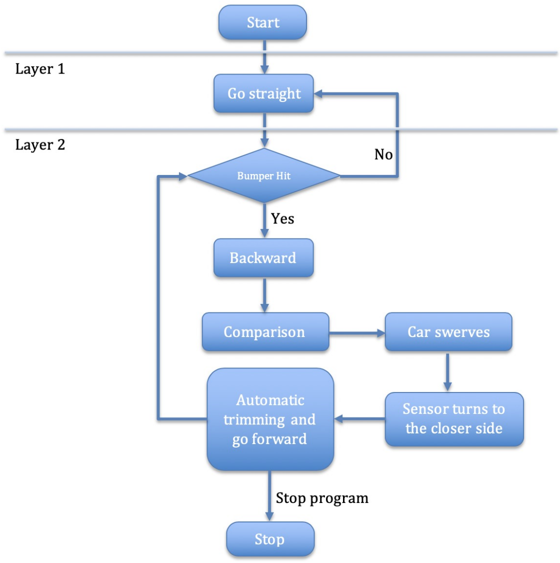

Figure 2: Subsumption architecture

Sensor Range (Meters)	Average Collision (Times)	Variance
0.10	7.6	0.49
0.15	6.2	0.18
0.20	6.4	0.49
0.25	5.9	0.10
0.30	4.2	0.18
0.35	3.1	0.10

Table 1: Collision Statistics

Sensor Range (Meters)	Average Time (seconds)	Variance
0.10	65.09	4,20
0.15	59.45	4.32
0.20	57.26	6.29
0.25	54.48	5.58
0.30	42.01	5.65
0.35	36.92	3.98

Table 2: Time taken Statistic

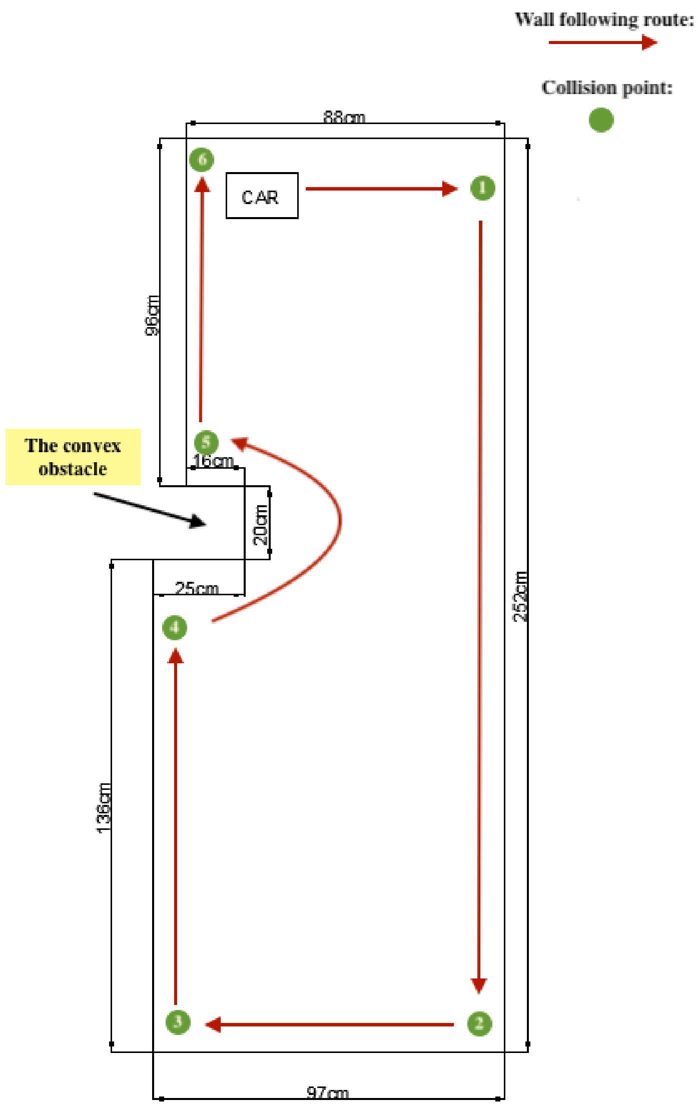

Figure 3: Optimal route

7 Contribution to report

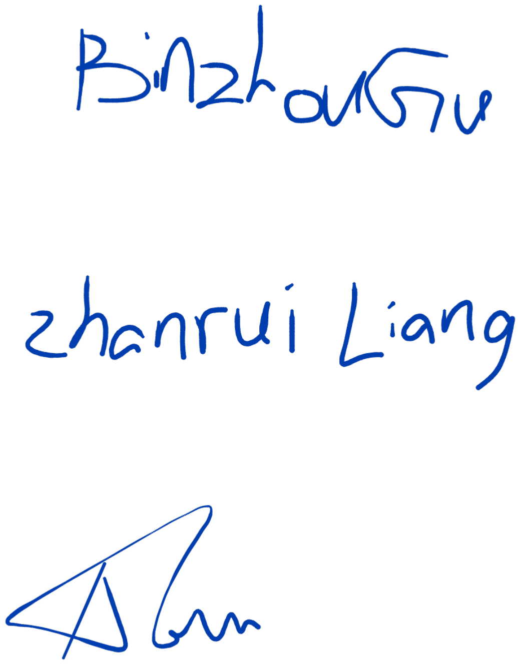

Figure 4: Signature
We are happy to be judged as having contributed equally.