International Journal of Advances in Computer Science & Its Applications – IJCSIA
Volume 4: Issue 4 [ISSN 2250-3765]
Publication Date : 27 December,2014

A Corner Differentiation with Ultrasonic sensors for Indoor Robot Navigation

Kuo-Yi Chen and Ren-Yi Huang

***Abstract*—With the growing trend of indoor mobile robots in the present day, such as elder caring and shopping helper, the issue of indoor robot navigation is becoming very important. In order to navigate mobile robots walk around in a room environment safely, the building of an indoor map is critical. However, the corner differentiation is usually becoming a significant issue. A robot should visit all corners and their consisting planes in a room correctly. Therefore, an efficient corner differentiation approach is essential for an indoor robot. In order to improve this issue, an effective corner differentiation is proposed in this paper to develop an indoor map building process.**

Keywords—mobile robot, indoor map building, corner differentiation.

I. Introduction

Nowadays, mobile robots play very important roles in our society. For example, robots already been used on elder caring, medical operations and transport business. The use of robots can reduce the human resource requirement, and provide the services to human. Due to provide for human, the indoor mobile robots are becoming a main stream since human spend the most of time to stay in indoor environments.

In order to let a mobile robot walk around safely in an indoor environment. The indoor map building is required. For indoor map building, the distance measurement devices are usually used. The common distance measurement devices such as Ultrasonic, Infrared Rays and Leaser are usually used to reach this goal. These devices can be used to determine the distance between walls/obstacles. With mobile robots walk around in an indoor environment, the map of space can be logged via these distance measurement devices. Therefore, the indoor map can be built based on observed edges by the data of distance between walls/obstacles.

Kuo-Yi Chen
Department of Computer Science and Information Engineering,
National Formosa University,Taiwan, R. O. C.

Ren-Yi Huang
Department of Computer Science and Information Engineering,
National Formosa University,Taiwan, R. O. C.

It is worth noting that no matter which distance measurement devices are used to build indoor maps, the corner issue is usually existed. Due to the reflection effect, the corner cannot be identified correctly without appropriately approaches. Moreover, the corners can be grouped as two major groups, concave corners and salient corners. The mobile robots have to identify these corners correctly to build an appropriate indoor map. Therefore, the effective corner differentiation approach is proposed in this study to improve the performance of indoor map building.

In order to reach our goal, the experiments are separated into three steps. First, an ultrasonic sensor is installed on our mobile robot as the distance measurement device. Secondly, we use this ultrasonic sensor to scan the indoor environment (a room) in various particular degrees, and then collect continuous edge distance for the further analysis. Finally, the corner differentiation approach is proposed to locate the reflection point of distance-based continuous sections, and build three groups of corners correctly. Thus the indoor map can be built to navigate mobile robots.

The rest of the paper is organized as follows. The background and related work are presented in Section 2. A case study that led to the motivation of this research is described in Section 3. The methodology and validation is detailed in Section 4. The experimental results are in Section 5. We then conclude our paper in Section 7.

II. Background and related work

In order to identify various corners, many researches already been studied. For example, Imen proposed a modular ultrasonic sensor to control mobile robot [1]. Kreczmer also proposed a study of relations objects reorganization with ultrasonic systems [2]. Sarabia proposed a model analysis of ultrasonic time-of-flight for overlapping echoes [3]. Senders proposed a corner-finding algorithm to solve this issue of corner differentiation. [4]

These solutions can be used to solve the most of corner differentiation issues, but they might not reach the better efficiency. Moreover, there experimental procedure of these proposed approaches are complicated. Therefore, the corner differentiation approach which is more effective and simple is proposed to improve the above issues.

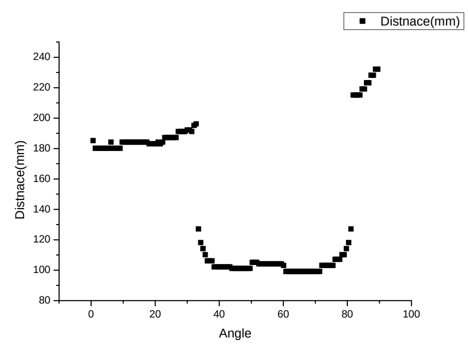
III. Motivation and Case study

In order to build a service-orient mobile robot, the ability of navigation is required in indoor environments. An indoor environment is determined as a space which is surrounded by several walls. These walls could be linked together to create a close space. In general, the regular wall is easy to be detected. However, the connected point of each wall might not be detected correctly as Figure 3.1 (a) and (b).

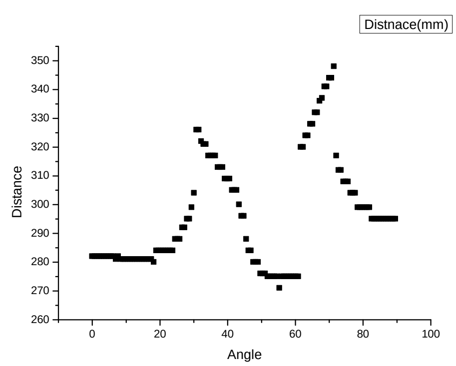
(a) Concave corners (b) salient corners

Figure 3.1 The Differentiation of Corners

Due to refraction effects of ultrasonic wave, these corners will be determined as follows in Figure 3.2. The experimental results can be recognized not identical as the shapes of these wall corners, thus the raw data cannot be used to build an indoor map directly.



(a) Concave corners



(b) salient corners

Figure 3.2 The distance measurement of various Corners

The fault identification might lead to incorrect indoor map building, and then mobile robot cannot locate itself well. It worth noting that the wrong map might not provide useful help

IV. Methodology and Validation

In order to improve the efficiency of corner differentiation, we propose a new approach which is named "the three stages corner differentiation" in this study. The flow of this new approach is shown as follows.

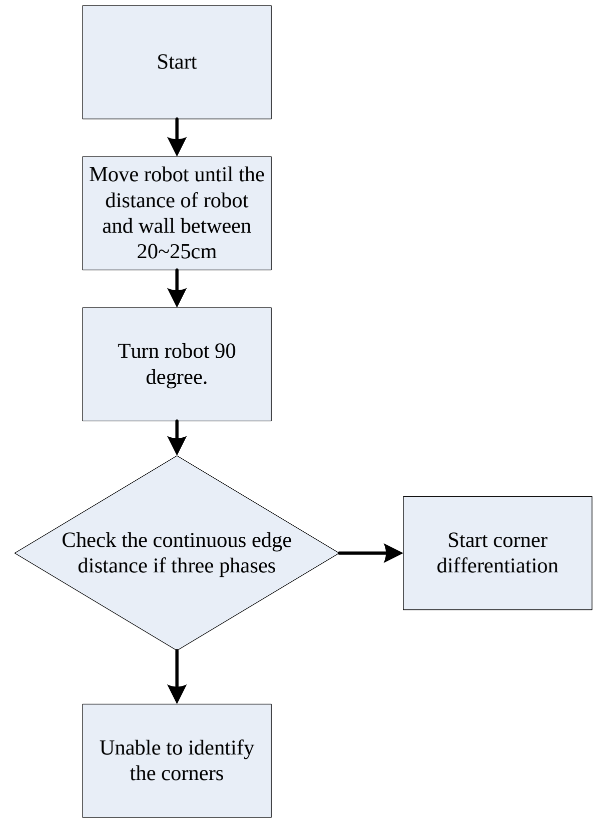


Figure 4.1. The test of continuous edge distance with three phases

In the first stage, the robot will determine the distance which is between sensor and walls/obstacles. Currently, the designed validated distance is between 20 to 25 cm. Therefore, in the first stage, the robot will move itself until the distances between sensor and walls/obstacles are valid. Furthermore, the robot will turn itself to face a wall/obstacle vertically based on the minimum distance. This wall which is faced by robot could be horizontal wall or vertical wall. When this stage is done, the corner differentiation approach can be process the next stages.

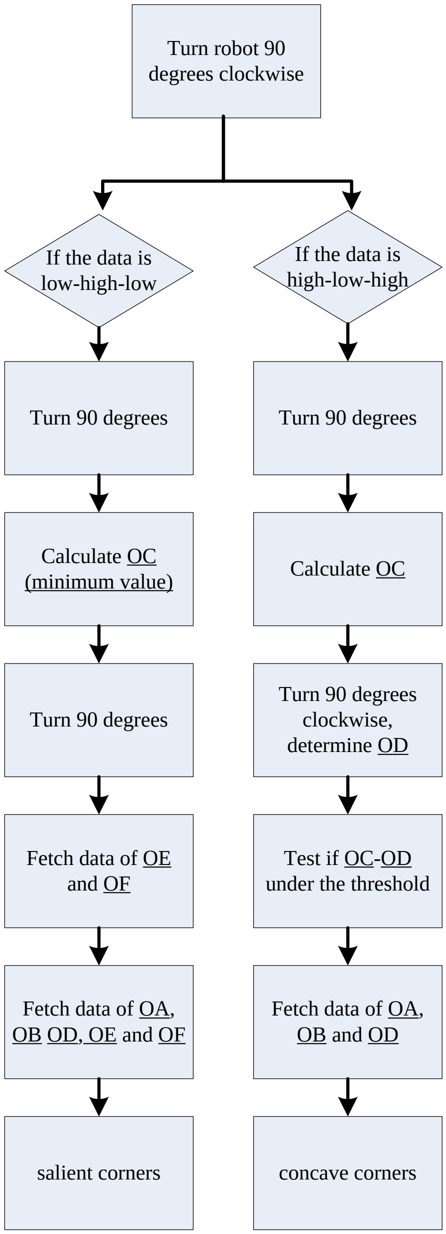
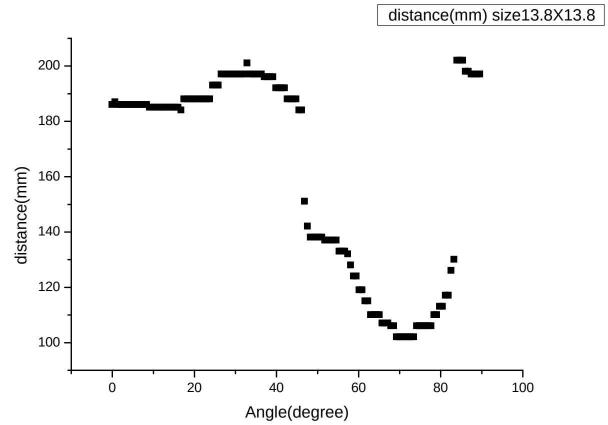
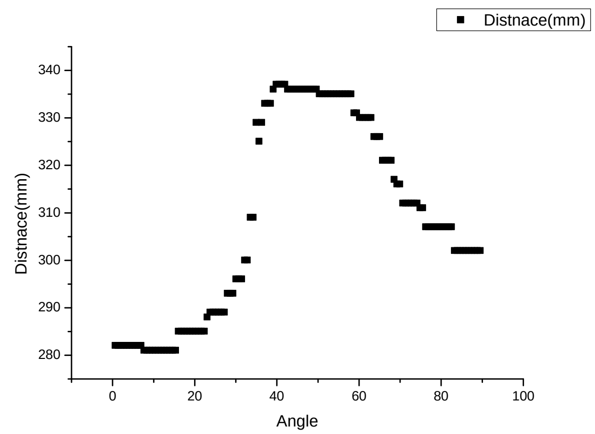


Figure 4.2. The test of continuous edge distance with three phases

Since the data of continuous edge distance is observed, the type of corners can be analyzed. The simple model is proposed in this study, the concave corners and salient corners both are presented as three phases of continuous edge distance. The data of concave corners is high-low-high. That means the continuous edge distance is shown as Figure 4.3 (a). On the other hand, the data of a salient corners is low-high-low, which is shown in Figure 4.3(b)



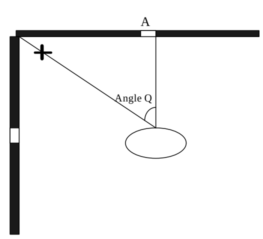
(a) Concave corners



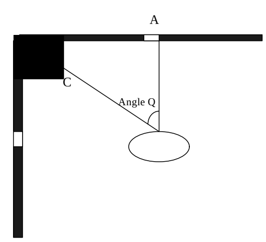
(b) salient corners

Figure 4.3. The patterns of continuous edge distances

In order to detail the proposed corner differentiation approach, the models of concave corners and salient corners are defined in Figure 4.4 as follows.



(a) Concave corners



(b) salient corners

Figure 4.4. The models of corners

When the data patterns of continuous edge distances are shown as high-low-high, the minimum distance between sensors and wall (OD) could be determined by sensor turning.

When the OD is determined, the concave corners can ob observed and revised.

It is worth noting that the differentiation of salient corners is different from concave corners. First, the low-high-low pattern is used to determine the process of salient corners. In order to observe the salient corners and revised them, the sensor will be turn 90 degrees and detect the minimum distance which is named OC as Equation 4.1. With a determined OC, the OA and OB in Figure 4.4 (b) can be observed.

$$\overline{OC} = \sqrt{\overline{OA}^2 + \overline{OB}^2} \qquad \text{(Equation 4.1)}$$

Moreover, current angle Q will be recorded as Degree a in Equation 4.2. With the Degree a, the OA and OB can be calculated. Therefore, the salient corners can be detected and revised.

$$Degree \quad a = a\sin(\frac{\overline{OA}}{\overline{OC}}) \qquad \text{(Equation 4.2)}$$

Based on the equations above, the concave and salient corners can be determined and revised to be drawn as a map. The result of experiments is shown in the next section.

V. Experimental Results

In order to validate the proposed corner differentiation approach, the experiments are setup as follows. The experimental results of concave corners are shown in Figure 5.1.

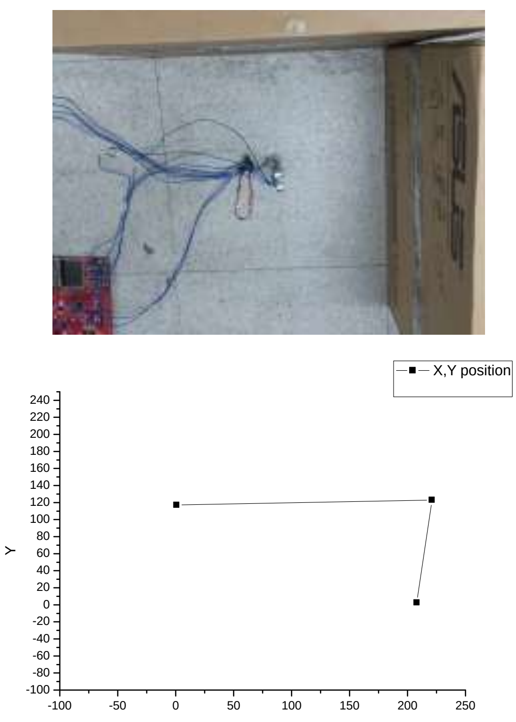


Figure 5.1 The experiment result of concave corners

On the other hand, the experimental results of salient corners are shown in Figure 5.2 as follows.

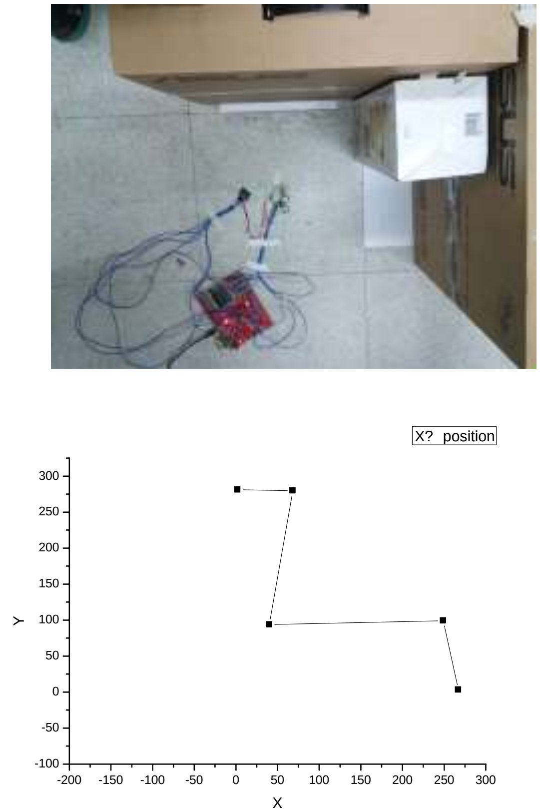


Figure 5.2 The experiment of salient corners.

VI. Conclusions

Bases on the approaches which proposed in this paper, the issue of corner detection and differentiation could be improved effectively. The proposed corner differentiation approach can identify three different types of corners effectively.

Acknowledgment

This work was supported by the National Science Council under Grant Nos NSC 102-2218-E-150-003

References

[1] Maâlej, I., M. Ouali, and N. Derbel. Modular ultrasonic sensor platform for mobile robot. in Renewable Energies and Vehicular Technology (REVET), 2012 First International Conference on. 2012. IEEE.

[2] Kreczmer, B. Relations between classification criteria of objects recognizable by ultrasonic systems. in Methods and Models in Automation and Robotics (MMAR), 2013 18th International Conference on. 2013. IEEE.
[3] Sarabia, E.G., et al., Accurate estimation of airborne ultrasonic time-of-flight for overlapping echoes. Sensors, 2013. 13(11): p. 15465-15488.
[4] Sanders, D., et al., Improving automatic robotic welding in shipbuilding through the introduction of a corner-finding algorithm to help recognise shipbuilding parts. Journal of marine science and technology, 2012. 17(2): p. 231-238.