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Arc/line segments extraction from unknown indoor environment with laser sensor

Rui-Jun Yan[1], Jing Wu[1], Ming-Lei Shao[2], Ji-Yeong Lee[2], and Chang-Soo Han[2#]

[1]Department of Mechatronics Engineering, Hanyang University, Korea
[2]Department of Mechanical Engineering, Hanyang University, Korea
(Tel: 82-031-400-0462)

[#]corresponding author: cshan@hanyang.ac.kr

Abstract: This paper proposed an arc/line extraction algorithm from the unknown indoor environment with a laser sensor. After getting the raw sensor data from laser sensor, the data is divided into different groups by checking the distance of two adjacent points. If the distance is bigger than a limit value, the sensor points in this group will be separated into two groups at these two points. Then the angle of three adjacent points is calculated and compared with another limit value. The group will be split into twos at the middle one of three points if the limiting condition is not satisfied. Moreover, the points in every group are attempted to extracting as a line segment firstly. If the extracted line is not smooth enough, the points in this group are extracted as an arc segment. After the segmenting process, these segments are merged by using the segments merging algorithm. In addition, the experiment results of arc/line extraction in unknown indoor environment by using a HOKUYO laser sensor located on a Pioneer mobile robot are presented.

Keywords: feature extraction, indoor environment, laser sensor and arc/line segments.

1 INTRODUCTION

The extracted segments can be considered as landmarks which take an important effect in the robot localization, navigation, perception and mapping environment. Most experiments, with laser sensor or vision sensor, of robot localization and mapping environment estimate the position of mobile robot using man-made landmarks, like Cup in [1] and Green Circle in [2]. However, it is difficult to put the landmarks into unknown complex environment. The reason of using landmark in these applications to correct the position of mobile robot is its low accuracy with only odometry, integrating the angular velocity and linear velocity over time for measuring the incremental distance and angle.

The data from the laser sensor are a collection of points with angle and distance, which must be extracted as line or arc segment because of the features cannot be identified by points alone. The natural corners are extracted from the natural indoor environment in [3], which are chosen as landmarks applied in the SLAM experiment for realizing the robot localization and mapping environment in [4]. Although the environment is constructed by using the mobile robot and laser sensor successfully, the curves in the experiment are expressed by some line segments which are not very accurate. To express the geometric shape of the feature appropriately, the raw sensor data are extracted as line segments and arc segments in this paper.

Two algorithms about arc/line extraction are proposed in this paper, arc/line segments segmentation algorithm and arc/line segments merging algorithm. Firstly, the sensor data are separated into different groups by checking the distance between two adjacent sensor points. For the data in every group, the angle of three sequential points is compared with a limit value. The group is divided into two groups if the condition is not satisfied. After finish the separation of raw sensor data, the data points in every group are extracted as a line segment or an arc segment. Some segments belong to the same segment actually maybe separated into different parts, which are merged by using the segments merging algorithm if the overlap distance between the segments is long enough.

There are five sections in this paper. The arc/line segments segmentation algorithm is shown in Section 2 and the segments merging algorithm is presented in Section 3. The experiment results prove the feasibility of the proposed in Section 4. Finally, this paper is concluded in the last Section.

2 SEGMENTS SEGMENTATION

The goal of this part is separating the raw sensor data into different groups and extracting the corresponding segments. The distance between point p_i and p_{i+1} is computed for checking whether these two points come from two different objects. If the distance is bigger than a limit value, the data set is divided into two sets. When the sensor points are from several objects, the distance of the end

points of two data sets from two different objects must be very long.

After finishing the first step, the angle between three sequential points p_i, p_{i+1} and p_{i+2} are calculated in Fig. 1 and compared with another limit value. If the angle is smaller than the restricted condition, the data set is separated into two new sets at the point p_{i+1}. When there is a corner in the environment, the angle between the points from this corner must be smaller and these points should be in two data sets.

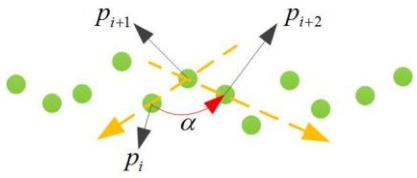

Fig. 1. Calculation of the angle between three sequential points: p_i, p_{i+1} and p_{i+2}

For every group of the sensor data, first of all, the line segments are extracted based on the data in this group. At the same time, the averaged distance between all the sensor points in the group and the extracted line segment is calculated, shown in Fig.2. The detailed calculation of average distance is expressed in Equation 1. After the extraction of line segments, the average distance is compared with a limit average distance. The arc segment is extracted based on the same group of data if the average distance of line segment is bigger than the limit value. The average distance of arc segment is also calculated and compared with the same limit value.

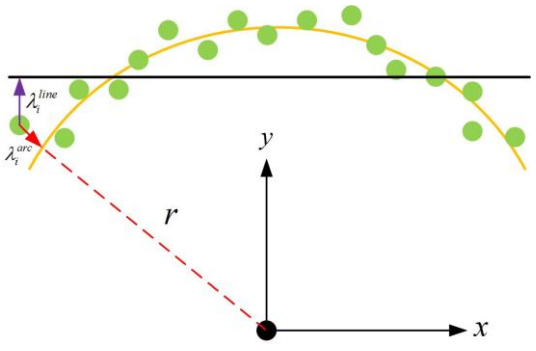

Fig. 2. Average distance between the sensor points and the extracted line or arc segment

$$\lambda_{ave} = \bar{\lambda} = \frac{1}{k}\sum_{i=1}^{k}\lambda_i \qquad (1)$$

If both of the two average distances of the group is bigger than the limit value, the two points with the biggest distance λ_i will be found when the data is extracted as line segment and arc segment separately. By comparing the distance λ of these two points in Fig. 3, this data set is divided into two sets at the point with bigger λ. Moreover, all of these steps are executed repeatedly until the raw sensor data in different groups are extracted as a line or an arc segment successfully.

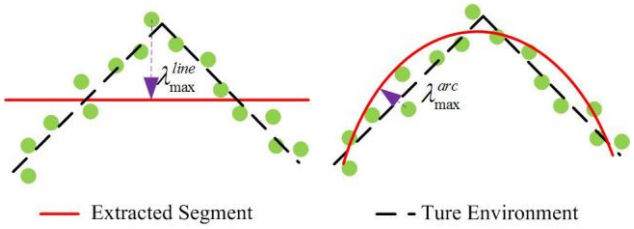

Fig. 3. Two points with biggest distance λ when the sensor data in this group is extracted as line segment and arc segment separately

3 SEGMENTS MERGING

Some segments extracted from raw sensor data by using segments segmentation algorithm maybe belong to the same segment, which should be merged as one segment. If the overlap distance between two line segments or two arc segments is bigger than a limit distance as in Fig.4 and Fig.5, these segments are merged as a new segment based on the sensor data in these two groups. The merging process is the same as the extraction part in the segmentation algorithm.

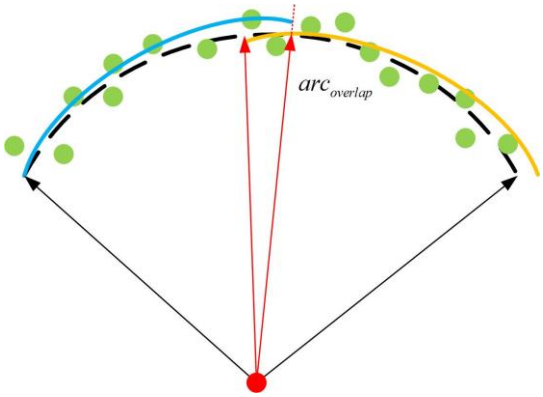

Fig. 4. Overlap distance of two arc segments which belong to the same segment actually

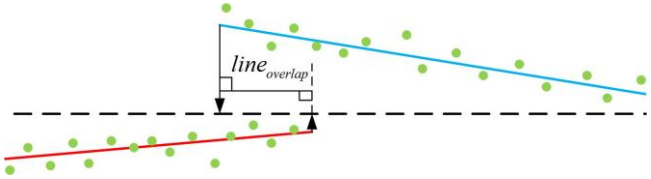

Fig. 5. Overlap distance of two line segments which belong to the same segment actually

4 EXPERIMENT

4.1 Experiment 1

The experiment 1 is done in the first underground floor of Engineering building #5 in Hanyang University, shown in Fig. 6, including the pictures of real experiment environment. The extracted line segments and arc segments by using the proposed algorithms in environment 1 is presented in Fig. 7. There are three figures of the segments extraction results when the mobile robot moves to different position. The circular objects and walls are extracted as the corresponding arc and line segments successfully. The green dash line in the figures is the range of laser sensor, of which the range is 270 degrees.

Fig. 6. Flow chart and real picture of experiment environment 1

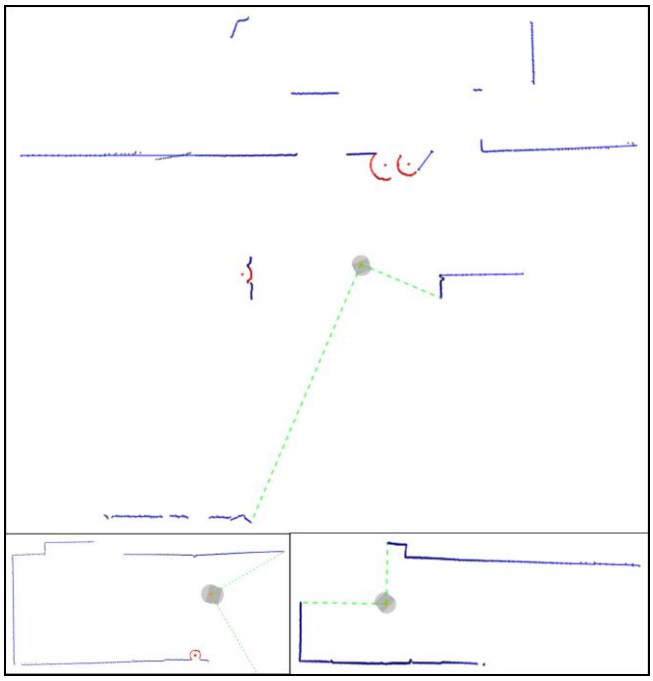

Fig. 7. Extracted arc segments and line segments from environment 1 with the different position of mobile robot

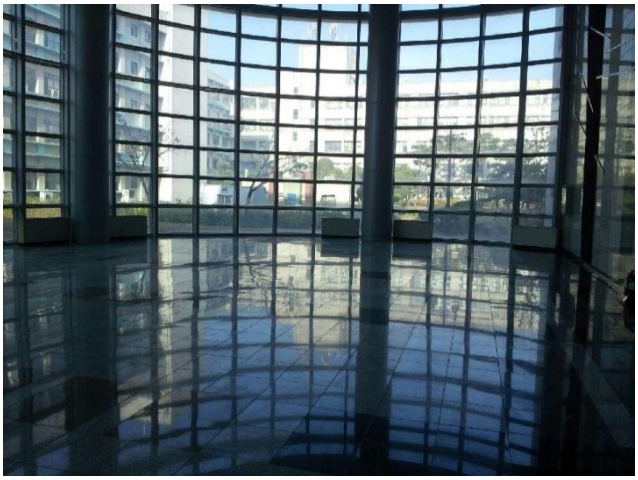

Fig. 8. Real picture of experiment environment 2

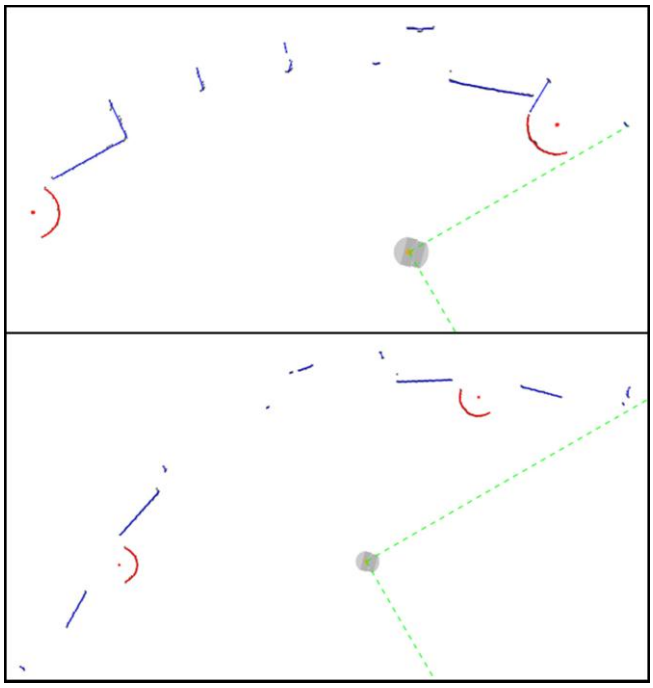

Fig. 9. Extracted arc segments and line segments from envir onment 2 with the different position of mobile robot

4.2 Experiment 2

The experiment 2 is done in the first floor of Engineering building #5 in Hanyang University in Fig. 8, the real picture of experiment. There are some columns and glass in this environment. However, the glass cannot be detected by laser sensor which can be seen in Fig. 9. The grey points in the figure are the raw sensor data and the blue line is extracted line segments. Arc segment is expressed by a red curve with an origin point. The circular columns are extracted as arc segments and glass are extracted as line segments successfully. The bigger grey point with two dash lines stand for the mobile robot and the range of laser sensor.

5 CONCLUSION

In this paper, the arc/line segments extraction algorithm are proposed, including segments segmentation algorithm and segments merging algorithm. The extracted segments can be chosen as landmarks applied in robot localization, path planning and mapping environment. Two experiments are done for checking the feasibility of proposed algorithm. In the experiments, the objects in unknown complex environment are extracted as line segments and arc segments successfully.

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