PROXIMITY LASER SCANNERS DATA SEGMENTATION

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ABSTRACT

The purpose of this work is to explain segmentation of data obtained from a proximity laser scanner using least square error method in Polar coordinates. The issue of occlusions is briefly explained together with solution to the problem. Segmentation results are shown on scans built for testing purposes.

1 INTRODUCTION

Nowadays, mobile telepresence robotic systems such as Orpheus [1], may be used for exploring dangerous areas, rescuing victims as well as for pyrotechnical purposes. These systems are often equipped with cameras, temperature sensors and also with proximity laser scanners to give the operator the best possible feeling as if on the robots place. Proximity laser scanners are essential when operating in foggy, smoky, or dark environments in which use of regular cameras brings no effect. Data obtained from laser scanners are used for avoiding obstacles, map-building and self-localization of the robot.

2 DATA SEGMENTATION

Data segmentation is a very significant task and upon its suitability depend all later work with these data leading to self-localization, map building, etc. Segmentation of data acquired from a planar proximity laser scanner by straight lines can be carried out by several methods. Least square error method which is implemented in this work is in its incremental form not very computationally heavy and proves to give satisfactory results.

Data are obtained as a vector of 361 measurements from proximity laser scanner (SICK PLS 101). Number of measurements may differ according to a laser scanner used. In this work, each measurement is an integer representing the range r to an obstacle corresponding with an angle ϕ of 0 ° to 180 ° with resolution of 0.5 °.

2.1 LEAST SQUARE ERROR METHOD

Least square method assumes that the best fitting curve for given data is the one with minimal sum of square errors. The method is implemented in Polar coordinates for two main reasons. Firstly, it is to maintain the geometrical character of the problem and secondly, to avoid the complexity of solution in Cartesian coordinates when working with slopes near zero and infinity.

In Polar coordinates, straight line not intercepting the pole O has an equation of the form $r \cdot \cos(\phi - \alpha) - \rho = 0$, where α is inclination of any line perpendicular to it, ρ is its perpendicular distance from the pole O. The distance d_i of point P[r_i, ϕ_i] is given by $d_i = r_i \cdot \cos(\phi_i - \alpha) - \rho$. The minimal square error condition is then

$$E = \arg\min_{(\rho,\alpha)} \sum_i^n (r_i \cdot \cos(\phi_i - \alpha) - \rho)^2 ,$$

where r_i and ϕ_i are Polar coordinates of an i-th data point and α and ϕ are line parameters that are searched for. The solution is as follows [2]:

$$\tan 2\alpha = \frac{p}{q} ,$$

$$p = 2 \cdot \sum \sum r_i \cdot r_j \cdot \sin(\phi_i - \phi_j) + \sum (1-n) \cdot r_i^2 \cdot \sin 2\phi_i ,$$

$$q = 2 \cdot \sum_i^n \sum_{j>i}^n r_i \cdot r_j \cdot \cos(\phi_i - \phi_j) + \sum_i^n (1-n) \cdot r_i^2 \cdot \cos 2\phi_i ,$$

$$\rho = \frac{1}{n} \cdot \sum_i^n (r_i \cdot \cos(\phi_i - \alpha)) .$$

Four quadrant arc tangent is taken in order to calculate the angle α. This sometimes generates negative values of ρ. In such cases, the sign of ρ is changed and π is added to α. The sums in equations for calculating p and q are stored in global variables and so only the new data are added in each step which speeds the algorithm up.

There are three conditions for the line to be finished:

1. when the mean distance from line to point exceeds ε

$$D_n = \frac{\sum_i^n (r_i \cdot \cos(\phi_i - \alpha) - \rho)}{n} > \varepsilon$$

2. when the distance of the current point to the line exceeds δ

$$|D_n - D_{n-1}| > \delta$$

3. when the distance of the previous point to the current point exceeds η

$$|r_i - r_{i-1}| > \eta$$

If any one of the conditions is fulfilled, the line is finished. The constants ε, δ and η are chosen suitably.

2.2 OCCLUSIONS

Occlusions are false lines connecting points that do not represent real walls or any other objects. They are usually caused by obstacles lying in front of other objects (e.g. walls), and what lies behind them cannot be detected from the current scanning position. An example of data segmentation without detection of occlusions is shown on **Fig. 1**, compared with segmentation implementing detection of occlusions. It is obvious from the picture that occlusions, if not detected properly, can cause immense problems in robot self-localization and therefore navigation.

In order to avoid errors caused by occlusions, a third condition $|r_i - r_{i-1}| > \eta$ evaluating the difference in distance between two successive points is added to the algorithm.

2.3 SEGMENTATION RESULTS

The following figures show the same scan of an area built indoors for testing purposes. A box is placed in front of one of the walls, which on the left picture when no occlusion detection is used causes a false wall (occlusion), while on the right one occlusion is detected.

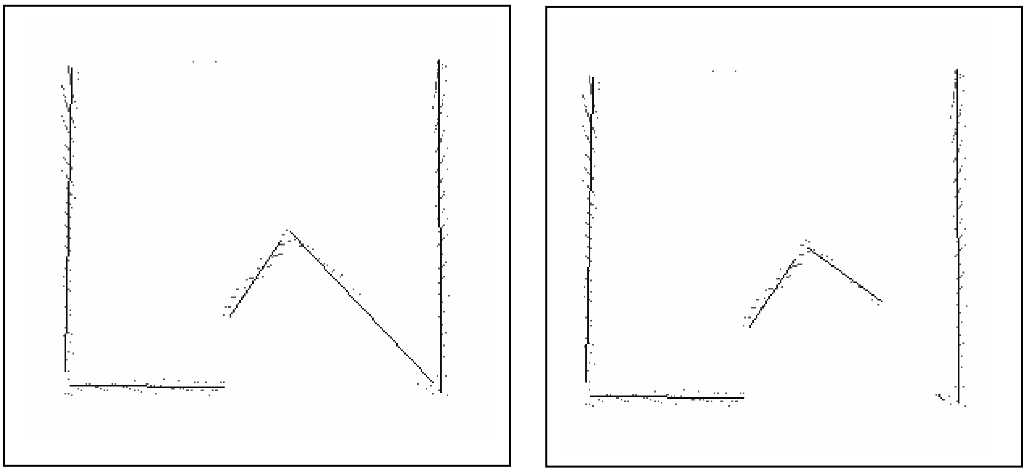

Fig. 1: *Left: data segmentation without occlusion detection; Right: data segmentation with occlusion detection*

3 CONCLUSION

Algorithms for data segmentation in Polar coordinates described in this paper are a part of semester work [3]. The method is programmed in Microsoft Visual C++, and allows use of different laser scanners with different number of measurements and resolution. Testing was carried out on several laboratory built areas, both clean and including obstacles with satisfactory results.

Segmentation algorithm will be used for self-localization in master thesis.

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