26th International Conference
ENGINEERING MECHANICS 2020
Brno, Czech Republic, November 24 – 25, 2020

PROBABILITY LINEAR METHOD POINT CLOUD APPROXIMATION

Králík J.[*], Venglář V.[**]

Abstract: *Fitting curves through point clouds is useful when the further computation is required to be fast or the data set is too large. The most common method to fit a curve into a point cloud is the approximation using the Least squares method (LSM) but it can be used only when the expected data have normal distribution. Data obtained from LIDAR often tend to have an error which can't be solved by LSM, like data shifted in one angular direction. The main goal of this paper is to propose more efficient method for estimation of obstacle position and orientation. This method uses curve approximation based on probability; this can solve some classic errors that appear when processing data obtained by LIDAR. This method was tested and was found to have a disadvantage: great demand for computing power; its more than ten times slower than classic LSM and in cases with normal distribution gives the same results. It can be used in system where the emphasis is on accuracy or in multiagent solution when working with big data set is not desired.*

Keywords: Point cloud, LIDAR, Curve approximation, Laser range finder, Localization.

1. Introduction

In every mapping or localization task, data must be obtained. Very common is to use LIDAR, but there is possibility that the data is angularly shifted to one side, due to surface properties or some kind of error (Fig. 1), especially if low cost solution is used (Krejsa and Vechet, 2018). This is not so big problem if the shift is smaller than desired accuracy, or a lot of data is obtained from several places with known position. In real situation when data is obtained via one robot which moves, the robot's position is acquired through odometry and it has worse precision than the obtained data. This leads to standard problem where the robot creates curved map of a straight environment.

The same problem occurs when curve fitting is required. The simplest and probably the most used method to obtain curve from point cloud is the Least square method (LSM) (Luo et al., 2008). But LSM only fits point cloud by curve that has the least square distance from all points, for some real data better approximation method is needed.

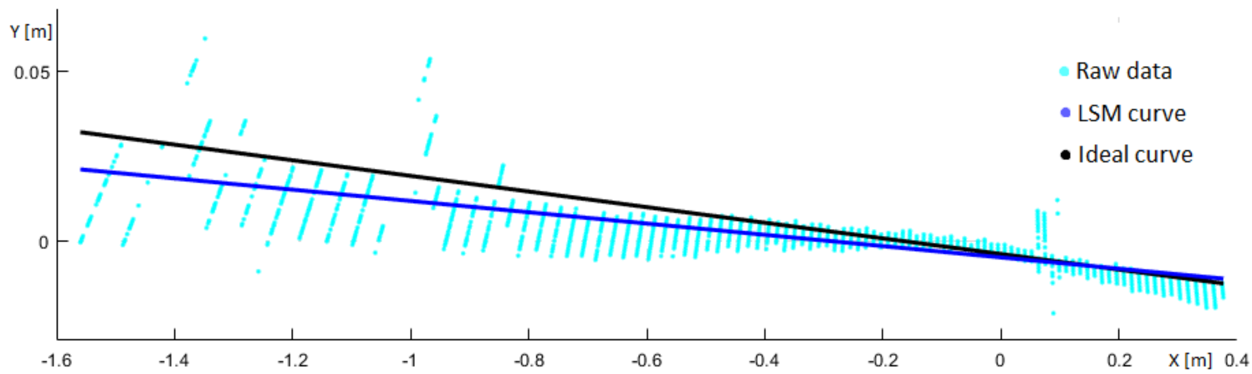

Fig. 1: Point cloud approximation by LSM and ideal curve.

[*] Ing. Jan Králík: Institute of Solid Mechanics, Mechatronics and Biomechanics, Brno university of technology; Technická 2896/2; 616 69, Brno; CZ, Jan.Kralik1@vutbr.cz

[**] Ing. Vojtěch Venglář: Institute of Solid Mechanics, Mechatronics and Biomechanics, Brno university of technology; Technická 2896/2; 616 69, Brno; CZ, Vojtech.Venglar@vutbr.cz

doi: 10.21495/5896-3-306

For this reason, the Probability linear method (PLM) is proposed. It incorporates probability as one of the parameters which is used for curve fitting. This article examines firstly the basic idea, then shows how it works and finally compares advantages and disadvantages of this solution

2. Methods

From human perspective the task to interlace cloud points with curve is simple, especially when we know (or at least expect) what the result should look like. From mathematical perspective is the process simple as long as the data have normal distribution, but when the data is shifted, rippled or distorted a problem occurs. For tests data shown in Fig. 2 are used. The data are divided to three single lines. LIDAR position lays on coordinates [0, 0].

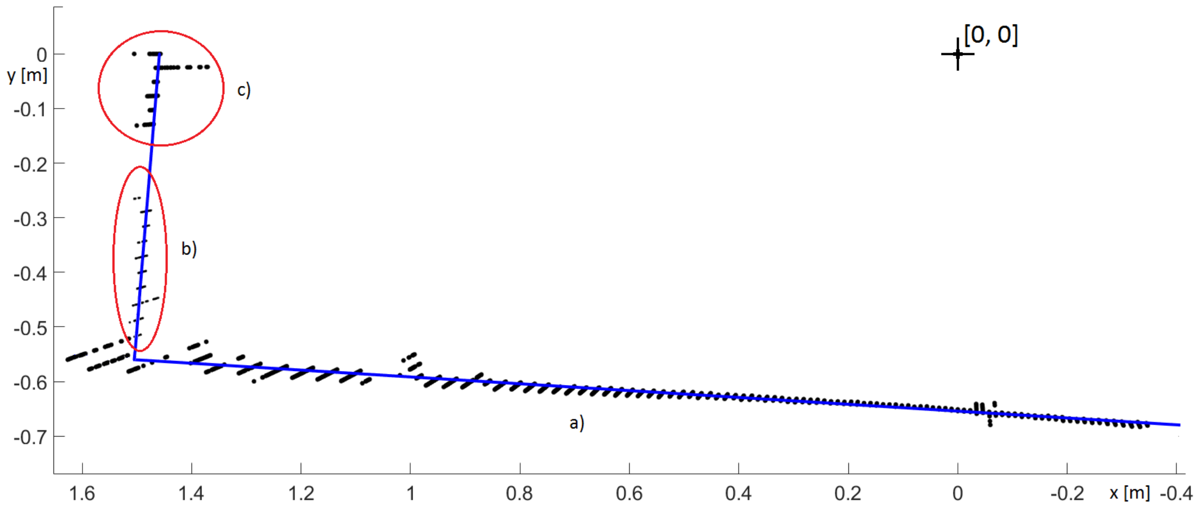

Fig. 2: Base point cloud with real obstacle line.

The data is separated for a test to three lines: a) with the data shifted, b) with approximately normal distribution, and c) with large error in measurement of one of the points (Fig. 3). As can be seen on line b), if data have approximately normal distribution, there is no reason to use other method than LSM. Both fitted lines are practically the same. However, in line c), the difference between LSM and PLM starts to be significant.

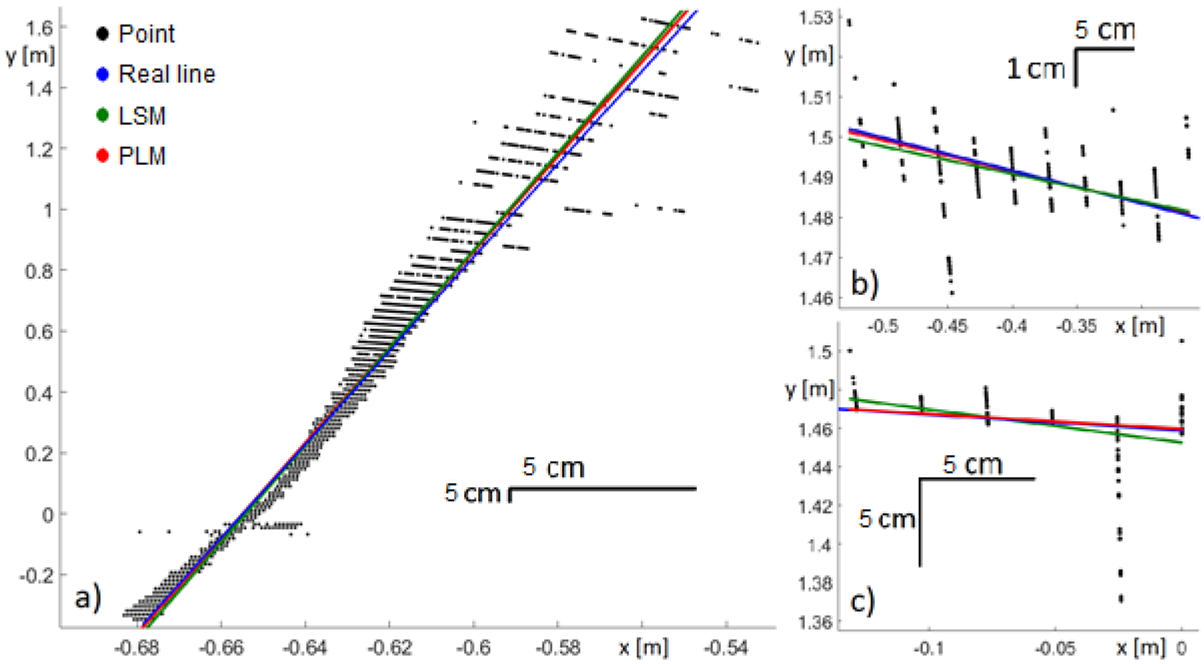

Fig. 3: Typical error a) shifted data; b) data with approximately *normal distribution; c) error in one point on line.*

This method assumes, that every LIDAR has measurement error linear dependent on the measured distance, so the data which are closer have more credibility. Other essential idea is that the data have centred characteristic, so even if there is somewhere majority of points on one side, and only minority on the other Fig. 3a, the real line is always in the middle. With these assumptions the Eq. (1) was derived.

$$min \sum \left(v \cdot \frac{1}{(1-P)^2} \right) \tag{1}$$

Where P is probability that a point lays on a curve (Eq. (2)) and v is distance between the point and the curve (Eq. (3)). In Eq. (2) is the probability counted as ratio of distance from curve (v) over distance from source (r, Eq. (4)), this ration is multiplied by constant of probability (p - in this case used resolution of LIDAR).

$$P = \frac{r}{v} \cdot p \tag{2}$$

$$v = \left| \frac{Ax+By+C}{\sqrt{A^2+B^2}} \right| \tag{3}$$

$$r = \sqrt{x^2+y^2} \tag{4}$$

After folding into one formula (Eq. (5)), the final equation is composed. It can be simplified to Eq. (6), which improves clarity and also reduces computing time.

$$min \sum \left(\left| \frac{Ax+By+C}{\sqrt{A^2+B^2}} \right| \cdot \frac{1}{\left(1 - \frac{(x^2+y^2)\cdot\sqrt{A^2+B^2}}{|Ax+By+C|} \cdot p \right)^2} \right) \tag{5}$$

$$min \sum \left(\frac{\left| \frac{Ax+By+C}{\sqrt{A^2+B^2}} \right|^3}{\left| \frac{Ax+By+C}{\sqrt{A^2+B^2}} \right| - \sqrt{x^2+y^2} \cdot p} \right) \tag{6}$$

2.1. Experiment description

The goal of the experiment is to compare LSM and PLM approximation. As a test data point clouds at Fig. 3 are used. The experiment has two parts. The first part compares LSM and PLM on all three lines (with different iteration step for PLM). The second part takes the line which has the largest difference between LSM and PLM, and shows dependency of the accuracy on the number of iterations. It has two benchmarking criteria, fitting accuracy and computing time. Each test was computed ten times and the resulting time was averaged. For the test computer with processor AMD FX 9590 and 32GB RAM was used. The program used was Matlab R2018a.

3. Results

The first part of the experiment came out as expected. For sufficient amount of iterations PLM method has better result, but it is much more time consuming. The biggest difference is on curve c). Against expectations in curve a) is only little difference between LSM and PLM. Slope-intercept form curve equation is used (y = mx b), Δm and Δb is difference between real and approximated curve.

For the second part of the experiment curve c) was selected. As can be seen on graph (Fig. 4), precision significantly increased when the number of iterations changed from 10 to 100, after that the it remained basically the same

Tab. 1 Results for curve a).

Curve a)	Gradient (m)	Y-intercept (b)	time [s]	Δm	Δb
Real curve	15.54	9.97	-	-	-
LSM	15.96	10.44	0.010	0.420	0.470
PLM 30	15.92	10.41	0.131	0.380	0.440
PLM 100	15.66	10.26	1.236	0.120	0.290

Tab. 2: Results for curve b).

Curve b)	Gradient (m)	Y-intercept (b)	time [s]	Δm	Δb
Real curve	-0.079	1.460	-	-	-
LSM	-0.068	1.464	0.009	0.011	0.004
PLM 30	-0.059	1.467	0.020	0.020	0.007
PLM 100	-0.078	1.461	0.163	0.002	0.001

Tab. 3: Results for curve c).

Curve c)	Gradient (m)	Y-intercept (b)	time [s]	Δm	Δb
Real curve	-0.079	1.460	-	-	-
LSM	-0.172	1.453	0.007	0.092	0.007
PLM 30	-0.058	1.463	0.018	0.021	0.003
PLM 100	-0.078	1.462	0.123	0.002	0.002

Tab. 4: Results for curve c).

Iterations	Δm	Δb
10	0.2076	0.0261
20	0.0813	0.0086
30	0.0214	0.0032
50	0.0133	0.0011
75	0.0086	0.0009
100	0.0016	0.0019
150	0.0014	0.0016
250	0.0011	0.0012

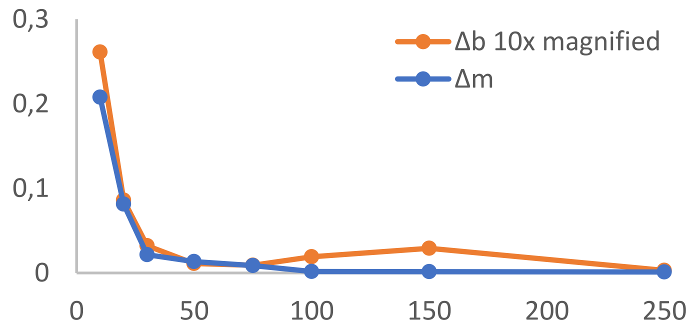

Fig. 4: Graph of error (Δb, Δm) on the number of iterations.

4. Conclusions

Probability linear method used for curve approximation in point cloud has good results, but needs a lot of computing time. The best improvement was observed on the short line with one sided error, but in all tested cases PLM has better results than LSM. The biggest disadvantage, long computation time, should be improved by implementing faster method to find minimum of function. The method can be used for other types of curves than line.

Acknowledgement

This research was supported by FME Brno University of Technology under the project FSI-S-20-6407 “Research and development of modern methods for simulations, modelling and machine learning in mechatronics”.

References

Luo RC, Jian-Xian Li, Chen C-T (2008) Indoor localization using line based map for autonomous mobile robot. IEEE Workshop on Advanced robotics and Its Social Impacts 1-6, doi:10.1109/ARSO.2008.4653586.

Krejsa J, Vechet S. (2018) Low cost laser rangefinder evaluation. In: Proceedings of 18th International Conference on Mechatronics - Mechatronika (ME) 433-436, doi:10.21495/91-8-433.