Probability linear method point cloud approximation

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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.

Introduction

Common way to obtain data in mapping and localization task is to use LIDAR, but there is possibility that the data is shifted to side, due some kind of error(Fig.1), especially if low cost solution is used (Krejsa and Vechet (2018)). This cause problem 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 fitspoint cloud by curve that has the least square distance from all points, for some real data better approximation method is needed.

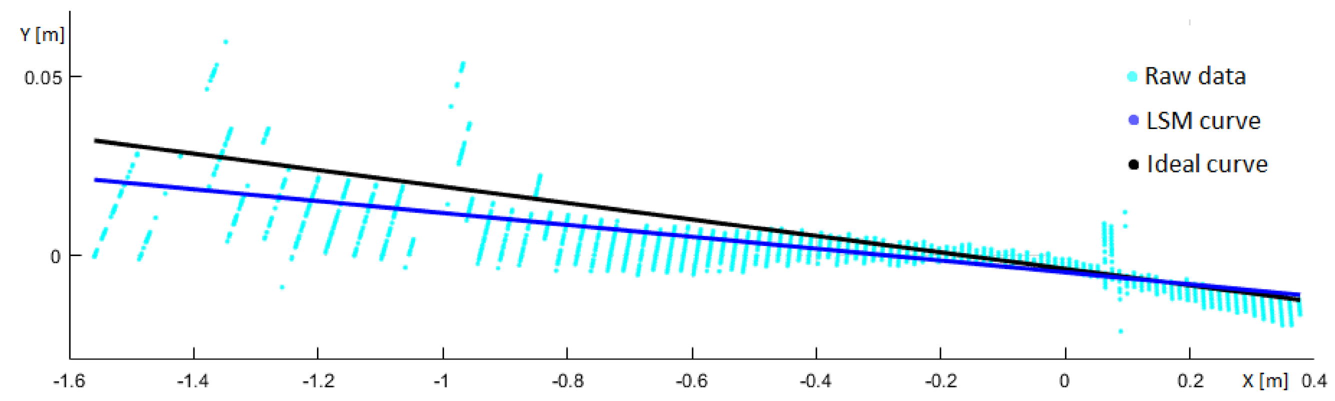

Figure 1: Point cloud approximation by LSM and ideal curve

For this reason, the Probability linear method (PLM) is proposed. It incorporates probability as one of the parameters which is used for curve fitting.

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 on Fig.2 are used. The data are divided to three single lines. LIDAR position lays on coordinates [0,0].

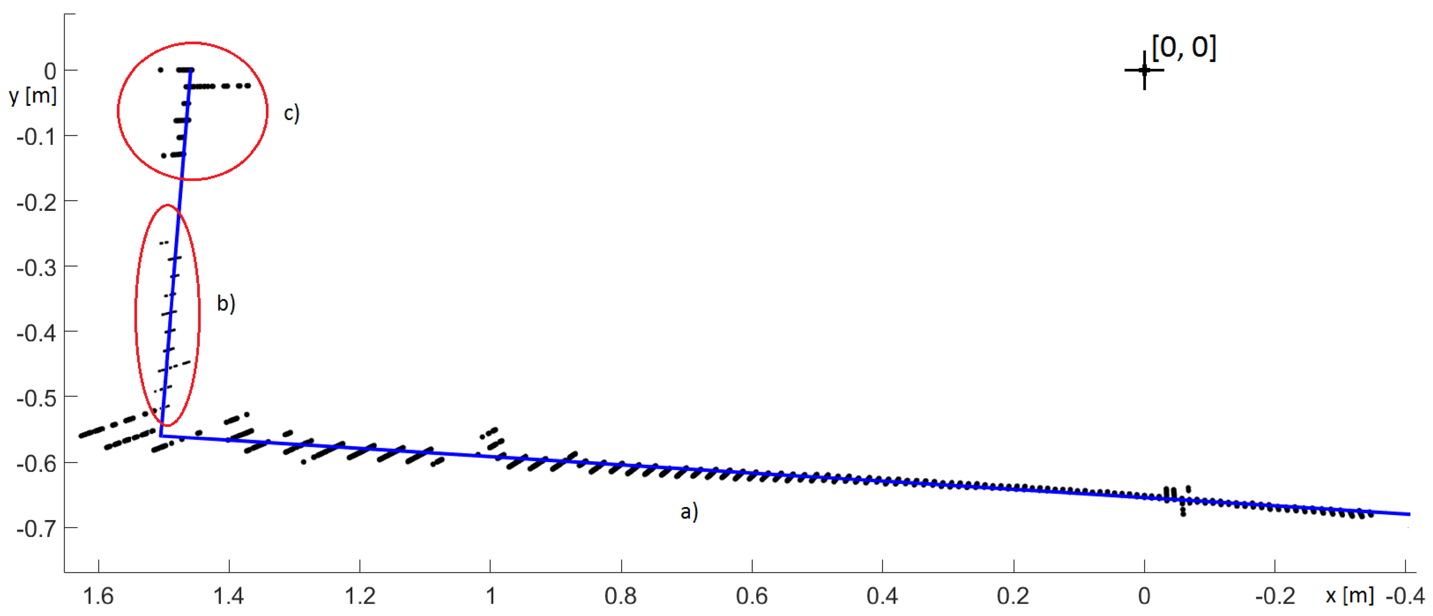

Figure 2: base point cloud with real obstacle (blue line)
three types of errors: a) with the data shifted, b) with approximately normal distribution, and c) with large error in measurement

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.3 a, 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 and v is distance between the point and the curve. This can be modifed to eq. 2, where x, y is coordinetes of each points and b, m is index of lope-intercept form curve equation ($y = m + b$)

$$\min \sum \frac{\left| \frac{mx-y+b}{\sqrt{m^2+1}} \right|^3}{\left| \frac{mx-y+b}{\sqrt{m^2+1}} \right| - \sqrt{x^2+y^2} \cdot p} \tag{2}$$

Experiment

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.

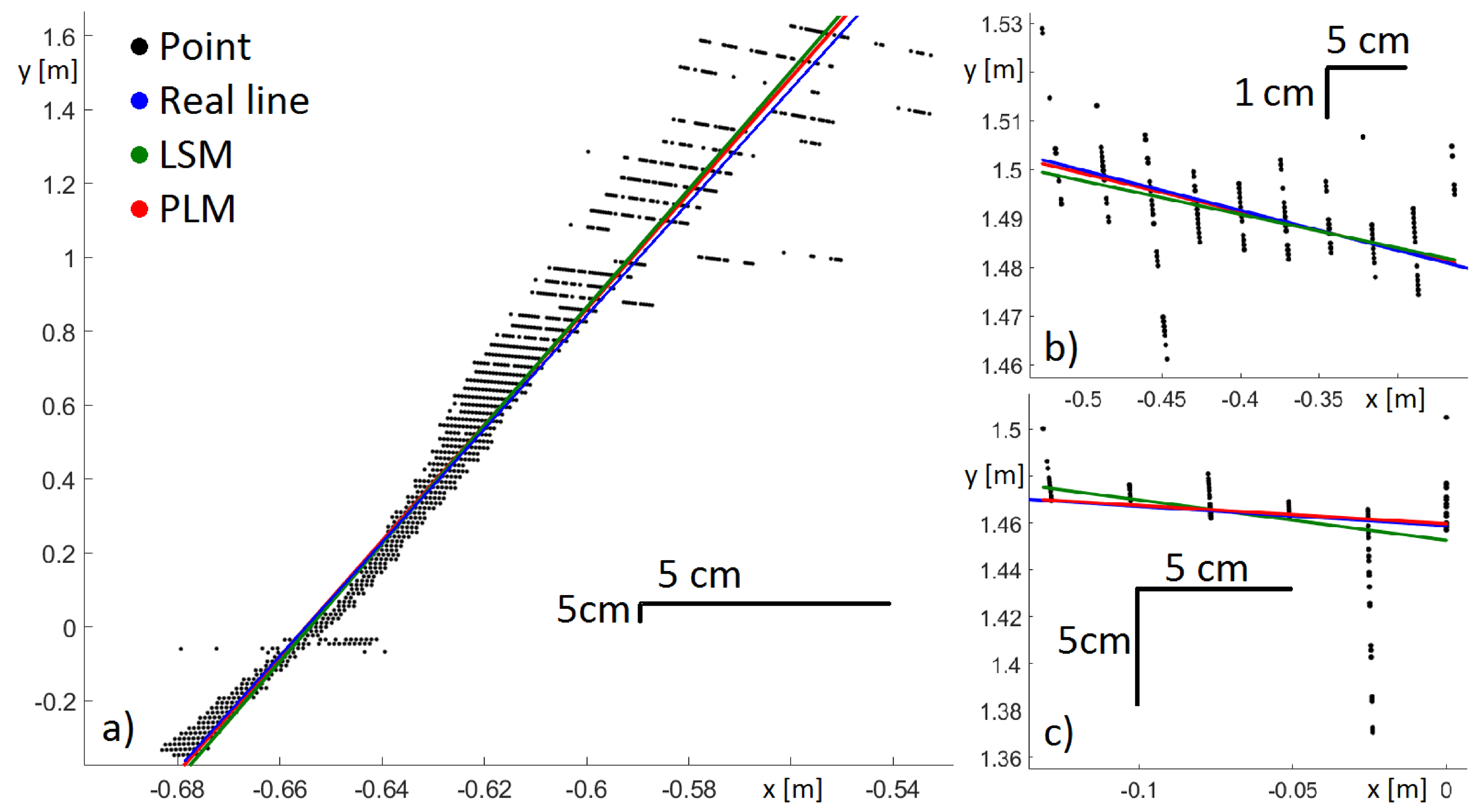

Figure 3: picture of typical error: a) shifted data, b) data with approximately normal distribution, c) error in one point on line

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 (for 30 iteration about three times longer time, and about twenty times longer time for 100 iterations). 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 ($y = m + b$), m and b is difference between real and approximated curve. This difference is four to ten times less than in LSM method.
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

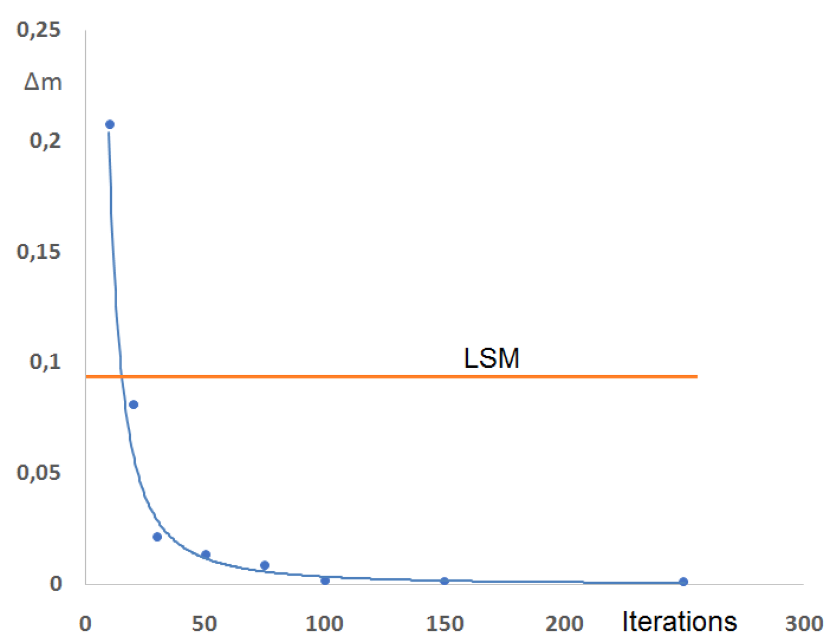

Figure 4: dependence of δm on the number of iterations

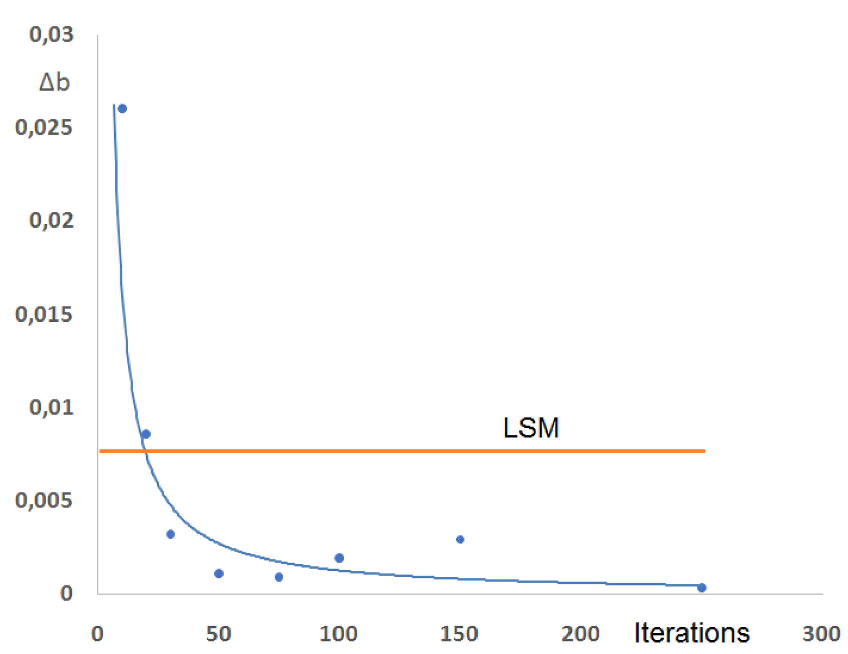

Figure 5: dependence of δb on the number of iterations

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 (multiparameter optimization method). The method can be used for other types of curves than line.

Acknowledgements

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

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