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BAYESIAN BASED LOCALIZATION OF MOBILE ROBOT VIA BEARING ONLY BEACONS

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Summary: *Presented paper deals with a global localization of an autonomous mobile robot in indoor environment. The method is based on the application of Bayesian filter algorithm that processes the bearing only beacons information. The method can successfully localize the robot even for high variances in beacons measurement and low resolution of beacons receiver.*

1. Introduction

Global localization is a key problem in mobile robotics, as correct location estimate is the key information for the motion planner algorithm. In outdoor environment the fusion of GPS data with odometry and other sensory inputs, such as compass is usually performed. In indoor environment the GPS data are unavailable and odometry information is usually fused with certain landmarks detection algorithm. Most of the nowadays used algorithms use image processing based extraction of landmarks and some version of simultaneous localization and mapping algorithm (Deans, 2005). Those methods can give solid results, but image processing is usually computationally expensive.

We present a method that is fast and reliable, but requires external beacons to be placed on defined positions around the robot. Presented method is therefore similar to landmark localization with known landmarks. The motivation for the method development comes from our needs, when the ability to drive through unknown environment is not required, but computational power is limited.

The environment is usually defined as a laboratory, ground floor or entrance hall, so the blue prints or some kind of a map is available. The beacons are placed around the robot near the walls to avoid collisions with robot or moving people. The robots moves in bounded environment, with goal positions given as external input. To plan the motion the estimate of current position of the robot (x,y coordinates and heading angle) must be known.

2. Materials and methods

The hardware principle of bearing only beacons is based on two independent devices. The first one is the beacon itself. Each beacon has its own unique identification number and transmits defined signal uniformly around in 180 degrees range. The second device is beacon-scanner that identifies the signal emitted from selected beacon. Unique ID solves the problem of identifying the landmark and its position. The beacon-scanner is only able to detect the bearing of selected beacon (not the distance), with the precision of 22.5 degrees. The precision is given by the hardware restrictions in the number of scanner sensors, which is 16

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sensors (in the range of 360 degrees) for beacons detection.

The beacon sensory information is n-dimensional vector of detected beacon ID and relative angle measured. As the global positions of detected beacons are know, the information is used to estimate the robot pose. Method that produces such estimate is based on Bayesian filter (Thrun, 2005) and is shown in table 1.

1	Bayesian_filter($Bel\left(\mathbf{X}_{k-1}\right), u_k, z_k$)
2:	for all x_k in $\mathbf{X}_k$:
3:	$\overline{Bel}\left(x_k\right) = \sum_{x_{k-1}} P\left(x_k \mid x_{k-1}, u_k\right) Bel\left(x_{k-1}\right)$
4:	$Bel\left(x_k\right) = \eta P\left(z_k \mid x_k\right) \overline{Bel}\left(x_k\right)$
5:	return $Bel\left(\mathbf{X}_k\right)$

Tab.1: Algorithm of the Bayesian filter

Where $Bel\left(\mathbf{X}_{k-1}\right)$ is the belief that represents information about x_k state of the robot in previous time step *k*; u_k is the action preformed in actual step (e.g. forward, left, right,…); z_k is the actual measurement of detected beacons; $\overline{Bel}\left(x_k\right)$ is predicted belief based on probabilistic motion model $P\left(x_k \mid x_{k-1}, u_k\right)$ and previous belief; $P\left(z_k \mid x_k\right)$ is probabilistic model of the measurement, it represents the probability that robot can measure observed data z_k in given state x_k; η is a normalizing constant.

The algorithm is recursive and it works in two steps: first, the prediction of state estimate based on probabilistic motion model is calculated; second, the update of predicted state based on actual measurements (beacons relative angles) is performed. These two steps are calculated for all possible states. The estimate with maximum belief is selected as filter output and next step can be performed.

3. Results

Bayesian filter was able to estimate the position of the robot with sufficient precision. Apart from low resolution of the beacons scanner the probability of detecting the beacon was set to 0.5 to model dynamic obstacles. Therefore only 50% of visible beacons in the range of the scanner are used to generate the bearing information into the filter.

Typical course of the localization in progress is shown on Fig.1. On the figure one can see the initial position of the robot (it’s estimate forms additional input to the filter), depicted with black square, the goal position depicted with the target sign (goal coordinates are used as the input to the planner) and positions of the beacons, depicted as bold circular rings. Allowable area is shown in gray. The figure shows the sequence in position estimation, with both the coordinates and the angle. One can see that the initial error in angle estimate is immediately corrected.

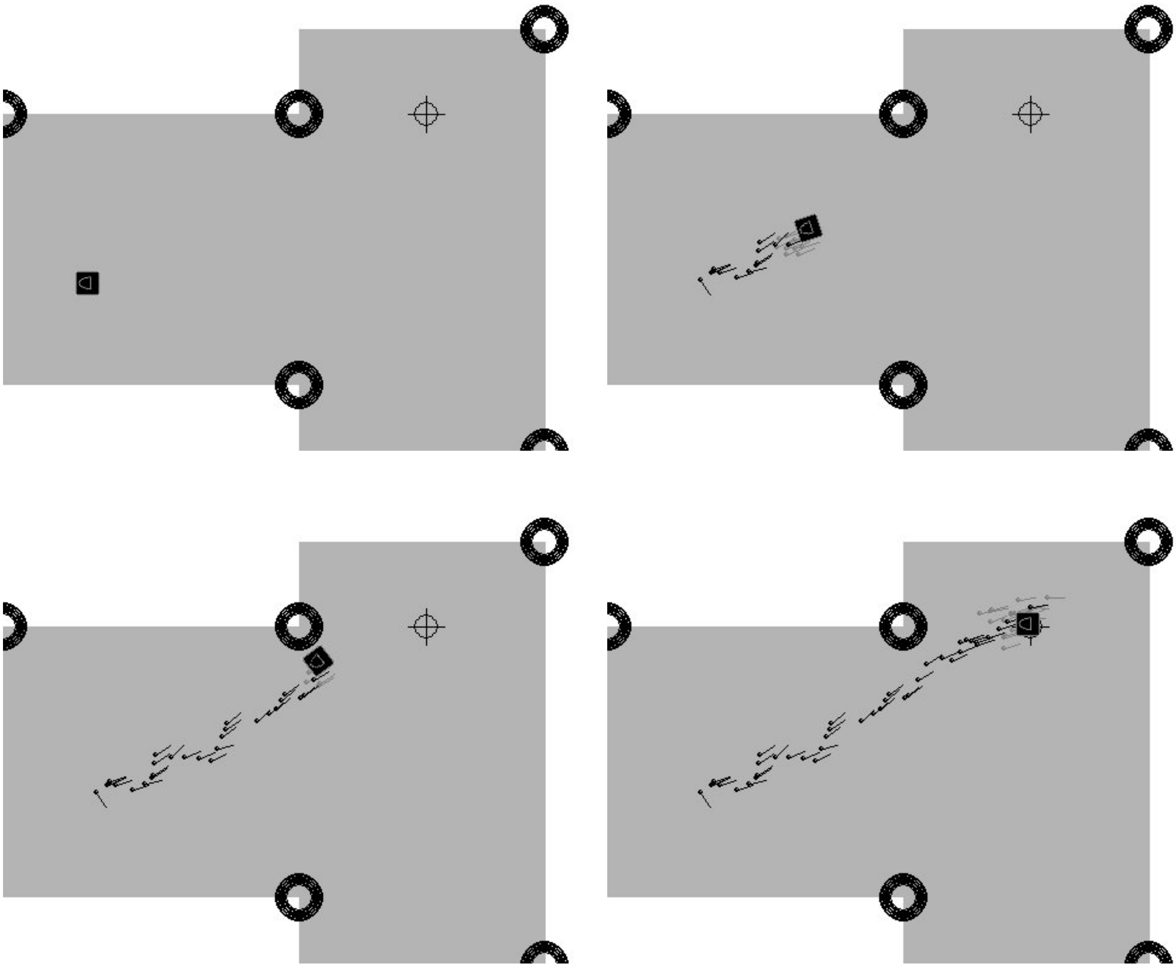

Fig. 1: Bayesian based localization during the motion from initial position to the goal. Beacons are depicted with bold circular rings.

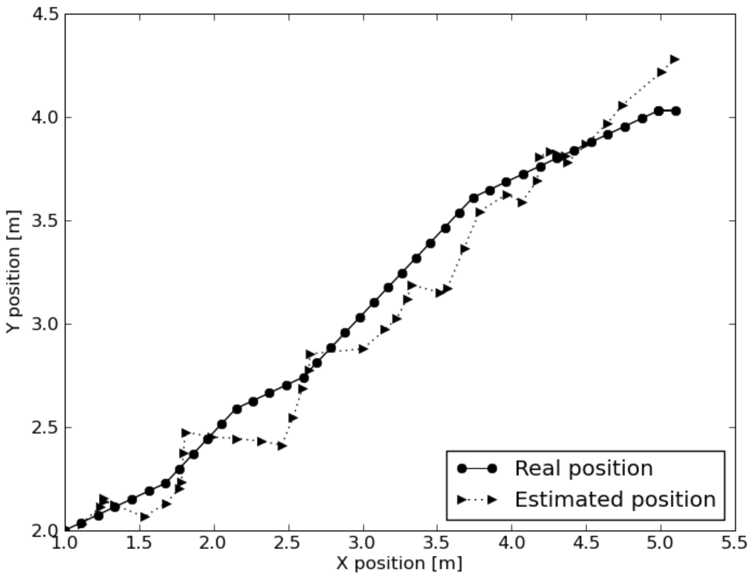

Fig. 2. Real position and estimated position comparison

The comparison of the real trajectory with the estimated one is shown on figure 2, while figure 3 shows the absolute value of position error. Only the coordinates are given (angle is omitted for the clarity). One can see that the maximum error was about 0.3 m. We consider such amount of error to be surprisingly low, given the low resolution of the scanner.

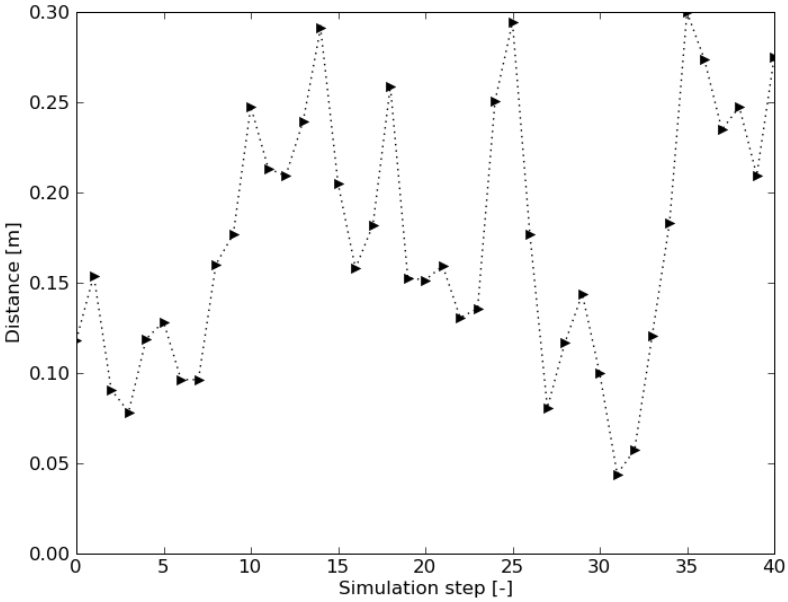

Fig. 3: The difference between real and true position of the robot for each preformed step.

The algorithm was verified on real robot with differential drives and the results correspond with the simulation.

4. Conclusion

Bearing-only beacons are cheap, easy to implement, but the precision in bearing angle detection is low. Therefore it was the objective of our experiments to develop and implement the localization method robust towards such imperfection. Presented paper shows that Bayesian filter based localization that uses bearing-only beacons measurements is reliable with sufficient precision. While the necessity of placing the beacons might be viewed as a drawback, low computational requirements and ability to localize the robot in arbitrary light conditions devote the method to be used in specific indoor tasks.

5. Acknowledgement

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