Kalpa Publications in Computing

Volume 14, 2023, Pages 38–41

Proceedings of V XoveTIC Conference. XoveTIC 2022

An approach for global localization in complex indoor environments based on topological maps

Diego Delgado-Mena[1], Sergio Lafuente-Arroyo[1], Saturnino Maldonado-Bascón[1], and Juan Antonio Castro-García[2]

[1] University of Alcalá, Alcalá de Henares, Madrid, Spain
diego.delgadom@edu.uah.es
sergio.lafuente@uah.es
saturnino.maldonado@uah.es
[2] University of Sevilla, Sevilla, Andalucía, Spain
jacastro@us.es

Abstract

One of the main problems in mobile robotics is to estimate the global position in complex symmetrical environments. Even when there are many devices or algorithms to achieve that goal, not all of them are useful in all kind of environments. GPS is typically used outdoors whereas algorithms based on Monte Carlo localization (AMCL) are used indoors. However, they present some disadvantages. Thus, the GPS commercial devices do not work inside the buildings and the AMCL algorithms are limited in symmetrical environments for the fact that they needs to detect remarkable differences in the environment. Due to the mentioned limitations we propose a global localization approach for symmetrical indoor environments based on the structure of topological maps. Here, geometrical and semantic information of static objects are considered, respectively, from LIDAR and RGB-D camera. Both sensors provide us, respectively, the information about occupancy areas and the scene perception. The proposed system is divided into four tasks. The first one is the classification of nodes according to their geometrical nature based on the LIDAR signature. The second stage is focused on object detection through a pretrained CNN based on YOLO (You Only Look Once) as model of convolutional neural network, which is able to work in real time. The third task corresponds to tracking and pose estimation of objects, where is necessary the information from YOLO and the depth data from camera. Finally, the last task consists of estimating the robot's global pose on the map from the output of object detector, their relative distance and their estimation pose. This algorithm compares the structure of detected nodes and objects with the structure defined on a reference annotated map. In order to match the degree of similarity of both structures we define a evaluation function and the highest value estimates the edge where is located the robot in the topological map. Our main contributions with respect to our previous work are the addition of depth of detected objects and the improvement of the evaluation function.

1 Introduction

The main purpose of this paper is to continue with the previous work [2] and develop a method capable of locating a mobile robot indoors, combining the visual recognition of objects with the use of topological graphs [1].

A topological graph allows us to have a simple representation of a very complex indoor environment with a high level of symmetry and with a large number of corridors. Regarding to our definition, the topological representation includes nodes and sub-nodes, where each node represents a relevant change of direction, bifurcation or end of aisle, and each sub-node contains the relevant information of the objects detected in the environment. This last information encompasses the objects class, the distance between the object and reference node on the edge, the disposition side of the object and the object visualization depending on the sense of robot motion.

The Figure 1 shows the block-diagram of the proposed method with three main modules: the first one consists of the classification of nodes based on Support Vector Machines (SVM) whereas the second stage corresponds to the tracking process and estimation of relative position of objects by using a YOLO-v3 detector and a tracker based on a other SVM model. Both processes use the robot odometry and depth information from RGB-D camera. Finally, the third stage deals with the evaluation function to estimate the global pose of mobile robot according to a preloaded map.

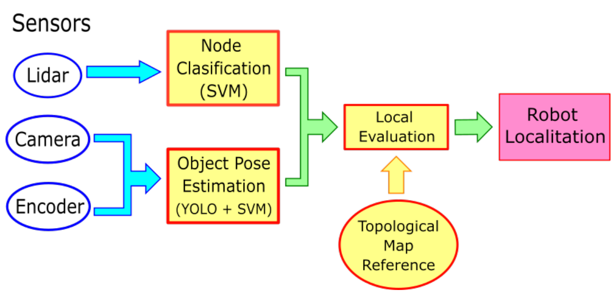

Figure 1: Overview of the proposed system.

2 Experimental Results

In this section, we proceed to comment the results from global localization with our approach. The workspace corresponds with the third floor of Polytechnic School of the University of Alcalá, which presents a complex and symmetrical environment. To evaluate the global position, all sections of the third floor are considered. (see Figure 2).

Table 1 summarizes some of the highest weights from matrix W_1, W_{12} and W_{123}. These matrices contain the results from the evaluation function to establish the correspondence between nodes and objects from the preloaded map and the detected ones. This method evaluates the nodes class, the distance between nodes, the objects class and the distance of objects to the reference node. In the first matrix (W_1), results are saved for only one Edge (two nodes); with only one iteration the information is not enough because there are many edges with the same

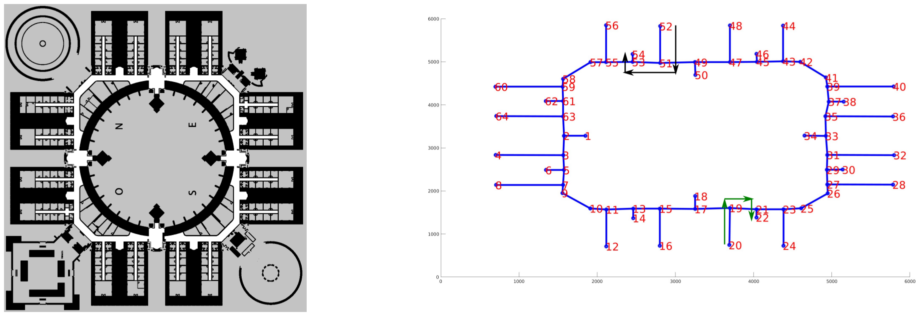

Figure 2: Metric and Topological map from EPS building.

weight, so is necessary to iterate more times. Thus as the robot moves through the environment, the weight that determines the global position on the map converges, thus discriminating the non-possible areas. These weights values are saved in the matrices W_{12} and W_{123}, that correspond to the evaluation of two and three edges crossed respectively. The true path taken by the robot in the experiment links nodes 20,19,21,22 (see Fig. 2).

		Green Arrows	Black Arrows
W_1	Visited Nodes	(20,19)	(52,51)
	Weights	0.604	0.612
W_{12}	Visited Nodes	(20,19,21)	(52,51,53)
	Weights	0.359	0.345
W_{123}	Visited Nodes	(20,19,21,22)	(52,51,53,54)
	Weights	0.235	0.216

Table 1: Results of evaluated global position.

3 Future Work

The line of future work is related with the improvement of tracking and evaluation pose. The tracking allows us to follow the objects detected on the Edge. Our current algorithm only makes the tracking and estimate the distance between the object and reference node. This estimation sometimes is not correct for objects with a distance over 15 m from camera. Thus, the process of tracking does not work correctly sometimes because multiple detections are generated for the same object. The proposals described above will serve to increase the discrimination cost of the evaluation function between nodes.

In addition, the evaluation function must include the directions of rotation to avoid evaluating paths that are not possible. This improvement will lead us to make more efficient the evaluation algorithm.

4 Acknowledgements

This work was supported by the projects: (a) AIRPLANE (PID2019-104323RBC31) and b) AAI (PID2019-104323RB-C32) funded by MCIN/AEI/ 10.13039/ 501100011033.

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