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A novel mobile robot localization approach based on classification with rejection option using computer vision☆

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ABSTRACT

In this paper, we propose a novel approach for mobile robot localization from images. The proposal is based on supervised learning using topological representations for the environment. The whole system comprises feature extraction and classification methods. With respect to feature extraction, we consider standard methods in digital image processing, e.g. Scale-Invariant Feature Transform and Local Binary Patterns. For classification, we apply machine learning methods with rejection option. A thorough assessment of the proposal is carried out using data from virtual and real indoor environments. Additionally, we compare the proposed architectures with classic localization systems using an omnidirectional camera. Based on the results, Spatial Moments combined with Bayes classifier is the best performing model, providing high accuracy rate (99.94%) and small computational time (47.3μ s and 0.165 s for classification and extraction, respectively). Finally, we observe that localization with rejection option increases efficiency and reliability of navigation in mobile robotics.

1. Introduction

Mobile robots have been widely used in industry for civilian and military tasks. For example, Urrea and Muoz [1] evaluated the performance of position control for a mobile robot in crops; Kim and Hong [2] proposed a distributed and autonomous routing algorithm for distributed mobile surveillance robotics platforms.

According to Bailey and Durrant-Whyte [3], mobile robot mapping and localization methods can be geometric, topological, or hybrid. Geometric maps represent the absolute position of the robot and landmarks. On the other hand, topological methods use graphs to estimate the environment topology. Cheng, Chen and Liu [4] stated that topological maps are simpler than geometric ones, requiring less computer memory, and, therefore, speeding up computational navigation processes. Hybrid methods are a blend of both topological and geometric techniques.

In an indoor environment, navigation systems such as Global Positioning System (GPS) can not provide accurate positioning

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information. In this way, several types of positioning systems have been developed to determine the absolute position of a mobile robot in this kind of environments, such as Bluetooth, Radio Frequency Identification (RFID), and image-based technologies. The last has become an important research topic in the development of mobile robots [5]. The advantages and disadvantages of these technologies are presented in Section 2.

In recent years, machine learning methods, such as artificial neural networks [6] and Support Vector Machine (SVM) [7] have been widely used for mobile robots navigation using images due to their capabilities of learning complex patterns and make intelligent decisions based on data [8]. Jodas et al. [9] presented a system to control the navigation of an autonomous mobile robot through tracks in plantations using SVM and an artificial neural network.

The aim of the paper is to propose a novel approach for mobile robot localization via classifiers with rejection option. For that, we adopt topological map information. In this context, the navigable area recognition is achieved by processing the input image and classifying them into states which represent the current robot context. Thus, the robot is able to determine its location into a topological map and also to navigate autonomously through the environment, reaching the desired destination.

In addition, we present a comparative study of several feature extraction methods and machine learning techniques in an indoor environment, resulting on two novel image datasets. The navigation and localization system is, initially, assessed with images generated from a virtual environment. After that, we use a GoPro camera to evaluate the system in a real environment. Also, we compare our results with a navigation system using an omnidirectional camera proposed by Marinho et al. [10]. Based on the results, combining Spatial Moments with the Bayes classifier has provided the best performing model with regards to both accuracy and computational time. Moreover, the results show that using the conventional vision camera is the best choice for the navigation task considering the accuracy and computational cost among the evaluated settings.

The next sections of this paper are organized as follows. Related works are presented in Section 2. Section 3 briefly introduces the feature extraction techniques and Section 4 describes the machine learning methods. Section 5 presents the methodology emphasized the proposed method, robot, topological map of the environment and datasets. Results and discussions of our experiments are explained in Section 6. Finally, Section 7 presents our conclusions.

2. Related work

There are several classes of technologies adopted in mobile robot localization and navigation, such as Wireless Local Area Network (WLAN), Bluetooth, Zigbee, Ultrawideband (UWB), Radio-Frequency IDentification (RFID), ultrasound, and computer vision. Alarifi *et al.* [11] categorized indoor positioning technologies according to the infrastructure of the system that uses them, see Fig. 1. The advantages and disadvantages of these technologies are presented in Fig. 2. Methods based on computer vision are a suitable choice for mobile robot localization. They do not require modification in the environment, they have low cost and are easily scalable [12].

According to Garcia-Fidalgo and Ortiz [5], vision-based navigation and localization systems can be grouped into global descriptors, local features, or Bag-Of-Words (BoW) schemes. There are several advantages for the use of computer vision in mobile robot localization. Regarding the global descriptors, they have low computational and storage cost. However, some global descriptors techniques have low robustness to occlusion and illumination effects. The local feature methods have high discrimination power. They are usually more robust to changes in scale and occlusions, illumination and rotation. The main drawback of such methods is

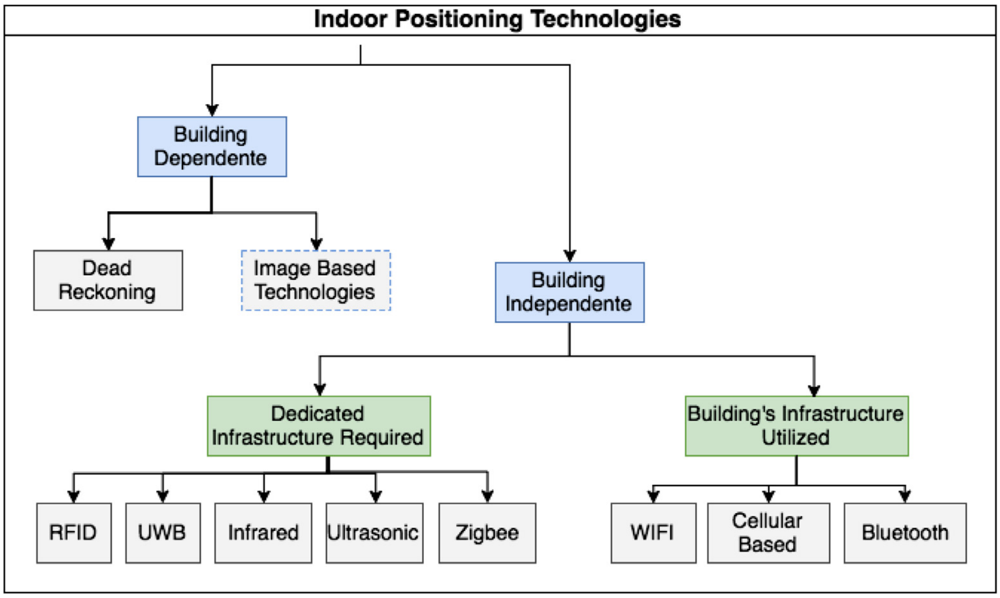

Fig. 1. Classification of indoor positioning technologies. Figure adapted from [11].