POSTER

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Abstract

In this study, we propose a novel illegal parking detection system based on simultaneous localization and mapping (SLAM). The system identifies the presence of illegal parking in real-time based on user-defined parking zones. Furthermore, considering the increasing deployment and pilot testing of unmanned patrol vehicles, we explore the application of this system to enhance the efficiency of automated illegal parking detection and management. The proposed system demonstrates high accuracy and real-time detection capabilities in identifying illegal parking and is expected to significantly contribute to addressing the issue of illegal parking in urban centers in the future.

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1 Introduction

The escalating issue of illegal parking in urban centers leads to traffic congestion, safety risks, and aesthetic decline. A promising solution to this problem involves employing simultaneous localization and mapping (SLAM) techniques. Initially, SLAM research primarily focused on geometric data, as exemplified by ORB-SLAM [Mur-Artal et al. 2015]. However, to enhance environmental understanding and mapping precision, the incorporation of semantic information has become essential. Consequently, deep learning has been integrated into SLAM, resulting in methodologies such as semantic SLAM. Drawing on recent advancements in SLAM research, we propose a system that effectively detects and addresses illegal parking using DSP-SLAM [Wang et al. 2021]. We introduce a novel approach and solution to illegal parking and explore the potential applications of this system, including the use of unmanned patrol vehicles.

2 Foundational Technologies

DSP-SLAM employs semantic object segmentation to identify objects from images and utilizes prior knowledge to estimate their shape and pose. This system generates a SLAM map and positions the detected object within this map. To visualize the object, DSP-SLAM constructs a dense 3D model based on the estimated shape and pose. Specifically, DSP-SLAM integrates ORB-SLAM2 [Mur-Artal and Tardós 2017] for SLAM map creation and combines Mask R-CNN [He et al. 2017] with DeepSDF [Park et al. 2019] to generate a detailed 3D model of the object.

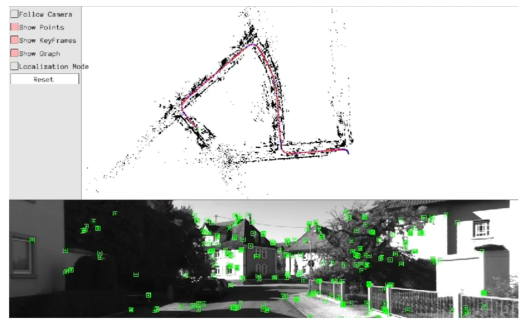

Figure 1: SLAM map construction

3 System design and Structure

Our system operates in three distinct steps. The first step involves SLAM map construction, as detailed in Section 3.1. The second step, setting up parking zones, which is outlined in Section 3.2. The final step, real-time detection of parked vehicles, is described in Section 3.3

3.1 SLAM map construction

SLAM is performed on the prepared dataset to understand the trajectory and surroundings, including the camera's position and pose, as illustrated in Figure 1. Subsequently, the SLAM map is constructed and stored. In this study, we utilized the ORB-SLAM2 algorithm to construct maps. Consequently, we generated a map consisting of a point cloud that represents the features of the surrounding environment and the camera pose at each keyframe.

3.2 Setting up parking zones

Since merely setting up a parking zone on the SLAM map does not provide sufficient visual cues, we incorporate an actual satellite image of the area. Figure 2 illustrates the process of aligning satellite images with SLAM maps and establishing parking zones. We visualize the SLAM map in an orthographic view, akin to looking down from above, as depicted in Figure 2 (a). We select two or more points along the camera's trajectory that are visible in two dimensions. Next, we create a correspondence by identifying the same two or more 2D points on the satellite image in the same order as

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(a) (b) (c)

Figure 2: (a) Selecting points on SLAM map in an orthographic view; (b) satellite image to align the SLAM map; (c) setting parking zones on the aligned satellite image

previously selected, as shown in Figure 2 (b). Utilizing these points, we perform similarity transformations, including translation, rotation, and scale adjustments, to align the orthophotos with the SLAM maps. Subsequently, we overlay the orthographic view of the SLAM map with the aligned satellite image, facilitating easy designation of parking zones by the user. The user can designate parking zones on the SLAM map while viewing the satellite image. Figure 2 (c) displays the legal parking zones set by the user, with the boundary coordinates of these zones recorded on the SLAM map. These coordinates are used for the real-time detection of illegally parked vehicles, as described in the subsequent chapter.

3.3 Real-time detection of parked vehicles

To detect illegally parked vehicles, the 3D model and coordinates of a specific vehicle, generated by DSP-SLAM's sparse SLAM backbone and prior-based reconstruction, are compared with user-defined parking zones. This comparison determines whether the vehicle is parked illegally.

$$S = \Delta P_0 P_1 P_2 + \Delta P_3 P_1 P_2 \tag{1}$$

$$\left| \frac{1}{2} \sum_{i=0}^{3} \| \overrightarrow{P_{car} P_i} \times \overrightarrow{P_{car} P_{(i+1) mod 4}} \| - S \right| \leq \zeta \tag{2}$$

In Equation (1), S represents the area of the user-specified parking zone rectangle, calculated as the sum of the areas of two triangles. Equation (2) outlines the criteria for determining the legality of a parked vehicle, where $P_i (i = 0, 1, 2, 3)$ denotes the vertex coordinates of the parking area rectangle, and P_{CAR} represents the vehicle's three-dimensional coordinates with height information removed. For any point P inside the polygon, we utilize the property that the sum of the areas of the triangles formed by connecting two neighboring vertices that constitute the polygon equals the area of the entire convex polygon. To compute the area of the triangle in space, we employ the cross product of vectors and introduce a tolerance ζ to account for floating-point mathematical errors. If a vehicle is within the user-defined legal parking zone, it satisfies Equation (2) and is therefore considered legitimately parked and visualized in blue. Conversely, if a vehicle is outside the legal parking zone, it is determined to be illegally parked and visualized in red.

4 Experiment

In this experiment, we utilized stereo images and LiDAR data from the KITTI dataset [Geiger et al. 2012]. Figure 3 displays a visualization of the legally and illegally parked vehicles detected by our system, alongside the legal parking zones designated by the user.

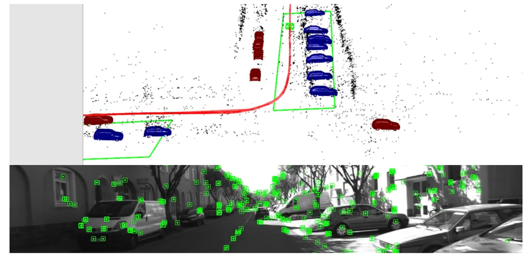

Figure 3: Legally parked vehicles across the borders

For visualization purposes, we employed Pangolin. The visual representation shows vehicles in blue located within the legal parking zones marked in green, and vehicles in red parked outside these zones, indicating illegal parking. However, ambiguous cases may be encountered, where the center of a vehicle straddles the boundary of a parking zone. As outlined in Section 3.3, our system determines the legality of a parked vehicle based on the vehicle's center point. Consequently, vehicles straddling the boundary of the lower left parking zone in Figure 3 are visualized in blue (legal), whereas those straddling the center parking zone are shown in red (illegal). For a more comprehensive understanding of the proposed system, please refer to the demonstration video[1].

5 Conclusion

In this paper, we proposed a SLAM-based illegal parking detection system and verified that the system is highly effective in recognizing illegally parked vehicles. The enforcement and management of illegally parked vehicles, typically handled by parking managers and police, are still largely performed manually. However, if our system is installed on the unmanned patrol vehicles currently being piloted, it is expected to automatically and accurately detect illegally parked vehicles, thereby saving labor and increasing management efficiency.

Acknowledgments

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[1]https://youtu.be/Y_G4cySxv2k