Multiple Camera based Lightweight Localization Technology for Indoor Parking lot

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***Abstract*—** Recently, there has been an active development in AVP (Auto Valet Parking) solutions for various last mile services. Despite the efforts, there is a limitation in reaching complete automation by only relying on autonomous vehicle sensors in complex and diverse parking environments. Especially in an indoor parking environment where GPS sensors are not supported, the autonomous vehicles have difficulties in locating themselves. In a such environment, the localization problem can be effectively coped by using smart infrastructure installed in the parking lot to analyze parking environment information. In this paper, we propose a method for mapping multiple camera images into a single grid map, and lightweight localization algorithm by tracking vehicles in parking lots, including environment where perceptive fields of surveillance cameras are not overlapping. By providing localization information of autonomous vehicles, the safety in AVP solution can be improved.

Keywords—AVP; Localization; Smart Infrastructure

I. Introduction

With recent advancement of technologies related to self-driving cars and smart infrastructures, the last mile service utilizing autonomous vehicle (AV) is under a spotlight. AVP solution, one of last mile services, has been getting a lot of attention. Despite the efforts to develop a stable AVP solution by researchers, the solution that is capable of handling various parking environment is still yet to be developed.

One of the limitations in reaching the stable AVP solution arises when an AV has difficulty in localizing itself in certain parking environments using common sensors such as camera, LiDAR, GPS and IMU. Specifically, in a featureless environment such as an underground parking lot where GPS is not supported, the performance of sensors on the AV is degraded. To overcome the localization problem, there are many studies being conducted to provide the positional information to the AV in real-time using the external sources such as smart infrastructures.

In this paper, our team propose a method that can analyze position and travelled paths of every car inside the underground parking lot in real-time by analyzing the surveillance camera images. In addition, our proposed algorithm can continuously track cars even in between cameras where there are no overlapping perceptive fields. By using our proposed method, not only the AV can localize its position, but the AV can take other cars' positional information, including cars in a blind spot, and take appropriate actions.

II. Related Work

A. Infrastructure data usage for localization

In autonomous valet parking systems, it is very important for the vehicle to recognize its own location. However, in indoor environments such as parking lots, it is difficult to realize its location using only sensors installed in the vehicle. To solve this problem in indoor environments, many studies have tackled it using external infrastructures. Some studies propose a smart parking system for autonomous vehicles using IoT [1,4,6,7,8,13].

In autonomous driving, the infrastructure analyzes areas beyond the vehicle's perception and can provide information to the vehicle to enable safer autonomous driving experience. There are related studies that use cameras for analysis [16]. In addition, there are studies that use Bluetooth beacon and LTE modem to estimate the location of vehicles in indoor parking lots [2,14,15]. However, few studies analyze images of cameras installed in parking lots to localize vehicles. Utilizing already installed surveillance camera system inside a parking lot is not only cost effective compared to newly installing sensors such as beacon and modems, but also convenient to apply the developed solution. Therefore, our team propose a method of accurately estimating the location of a vehicle only using surveillance cameras installed in a parking lot.

B. Re-Identification in non-overlapping areas

The ability to accurately re-identify individuals across non-overlapping areas of cameras is essential for various applications, such as surveillance, security, and social media analysis.

In the previous studies, there are various suggested methods to re-identify objects in non-overlapping areas using feature-based matching, appearance-based matching, and deep learning-based approaches. Feature-based matching methods use hand-crafted features, such as color and texture, to match individuals across non-overlapping areas [10]. Appearance-based matching methods use the entire appearance of an individual, including color and model, to match individuals across non-overlapping areas. Deep learning-based approaches use convolutional neural networks to learn features and match individuals across non-overlapping areas [3]. The deep learning-based approaches outperform the pre-existing methods on the benchmark datasets. However, this method does not guarantee a real-time performance and the amount of computation are very high, requiring high-spec hardware.

III. LIGHTWEIGH LOCALIZATION

As previously mentioned, current AVP solution has a limitation in localizing the cars by only using the sensors inside the AV. To tackle such problem, we propose a lightweight solution that can localize cars' real-time position using surveillance cameras inside the parking lot. Our solution consists of a real-time localization algorithm that can track and re-identify vehicles inside the parking lot and a user-friendly interface where a user can monitor the circumstances inside the parking lot in real-time.

In Section 3.A, we first introduce a method of representing images of multiple cameras on a single grid map. Then, we elaborate our new re-identification method utilizing license plate recognition and object tracking in Section 3.B. Finally in Section 3.C, we present the overall system of our lightweight localization solution.

A. Mapping multiple camera images in one grid-map

There are studies that have proposed methods for estimating positional information of objects in images using a mono-camera [5,9,11,17]. These deep learning based mono depth estimation studies have shown better-than-expected effects, but they are not free from the trade-off relationship between performance and computation. To reduce the computation power and to maintain the performance, our algorithm uses a light CNN based object detection model to detect cars in the images, and homograph projection to estimate depth of each detected cars.

The estimated position of cars is referenced based on the position of each respective camera. As shown in Fig. 1, the localized information is generated on different reference points, and the local coordinates needs to be transformed into a common reference to properly realize the absolute position of cars.

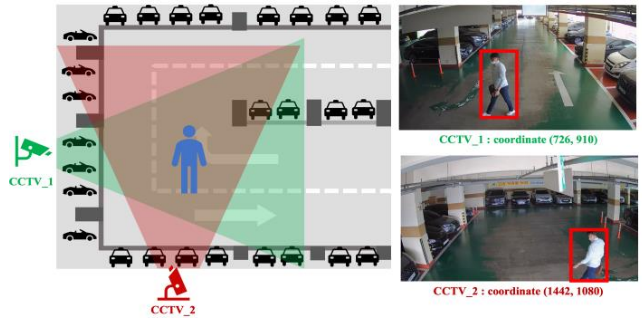

Fig. 1. Example of a figure caption. *(figure caption)*

To standardize the relative coordinates, we propose a Grid Map Global Mapping (GMx2) algorithm which converts the relative coordinate information from several cameras into an absolute coordinate information on a single grid map as shown in Fig.2.

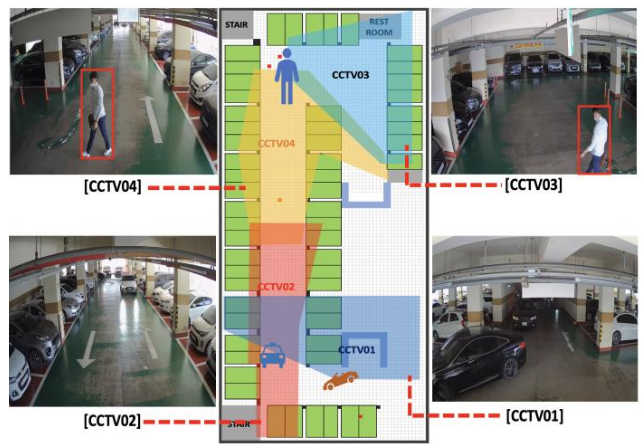

Fig. 2. Example of GMx2 (Grid Map Global Mapping)

B. Lightweihgt re-identification using LPR

In AVP, it is necessary to keep track of the real-time position of every vehicle from the moment entering the parking lot to the moment leaving the parking lot. To track vehicles' real-time position, the AVP solution needs to be able to assign a unique identification number to each car and continuously track each car even in the areas where there is no camera.

To track cars in areas without cameras, we apply real-time license plate recognition (LPR) technology. The lightweight Re-ID algorithm based on license plate recognition is proceeded as shown in Fig. 3. When the vehicle enters the parking lot entrance, it first recognizes the vehicle's license plate and assigns a unique tracking id. The vehicle is continuously tracked until the vehicle moves to an area without a camera. When the vehicle re-enters the area within a camera's perception, our algorithm starts tracking and assigns a new id. After the license plate of the car is recognized again, the newly recognized number is matched with the previously saved license from the database. If the same license plate information exists in the database, the current tracking id is replaced with the previously assigned unique tracking id.

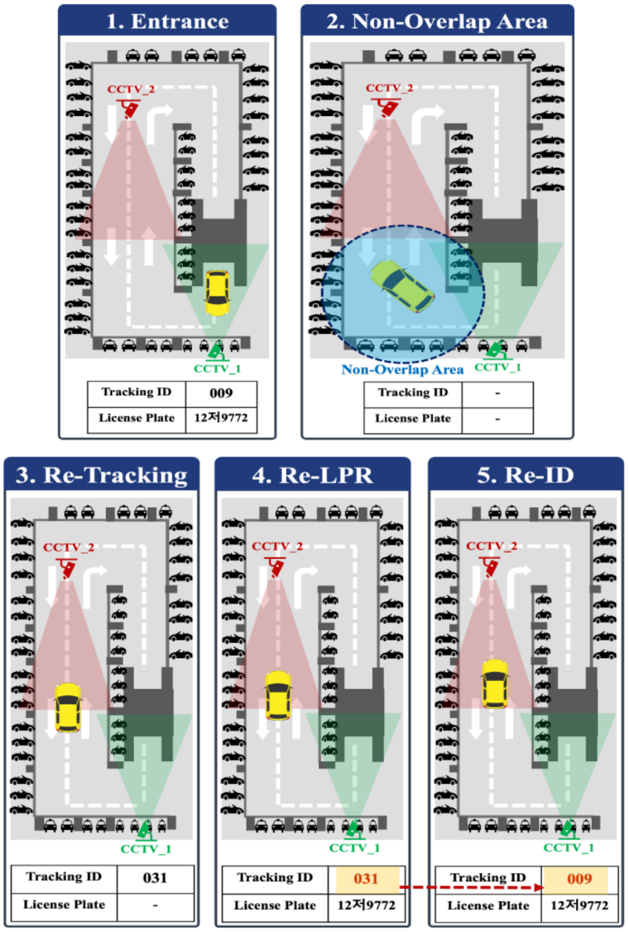

Fig. 3. Process of lightweight Re-ID based license plate recognition

The proposed lightweight Re-ID method requires much less hardware resources compared to the popular feature-based Re-ID methods. Our team developed the LPR model based on YOLOv4-tiny [12] with tensorRT, and have tested the license plate recognition of all vehicles in the parking lot in real time. Our algorithm can process four FHD camera video streams at a rate of 30fps using a NVIDIA A5000 GPU.

Fig. 4. Example of light weight Re-ID inferrence

C. *Lightweight Localization System*

The results from proposed localization, GMx2 and Re-ID algorithms is updated in a form of a grid map, and the grid map with analyzed information is transmitted to the autonomous vehicles. The example of lightweight localization support application is shown in Fig. 5.

Fig. 5. Example of vehicle localization support application for EAVP

IV. CONCLUSION

To solve the problem of indoor vehicle location estimation, this paper proposes a lightweight localization method using the smart infrastructure to assist AVP in an indoor parking environment. We develop a grid map that maps real-time position circumstances of multiple cameras. In addition, we develop a lightweight Re-ID algorithm that is very light and can support real-time applications. Our proposed AVP solution can contribute to development of a stable AVP service and can be further applied to other last-mile services applications.

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