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Machine vision based smart parking system using Internet of Things

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Abstract

It is expected that in the next decade, majority of world population will be living in cities. Better public services and infrastructures in the city are needed to cope with the booming population. City vehicles that cruising for parking have indirectly causing traffic, making one harder to travel around the city. Thus, a smart parking system can certainly lays the foundation to build a smart city. This paper proposed a cost-effective IoT smart parking system to monitor city parking space and provide real-time parking information to drivers. Moreover, instead of the conventional approach that uses embedded sensors to detect vehicles in the parking area, camera image and machine vision technology are used to obtain the parking status. In the prototype, twenty outdoor parking lots are covered using a 5 megapixel camera connected to Raspberry Pi 3 installed at the 5th floor of the nearby building. Machine vision in this project that involved motion tracking and Canny edge detection are programmed in Python 2 using OpenCV technology. Corresponding data is uploaded to an IoT platform called Ubidots for possible monitoring activity. An Android mobile application is designed for user to download real-time data of parking information. This paper introduces a low cost smart parking system with the overall detection accuracy of 96.40%. Also, the mobile application allows users to alert other car owners for any emergency incidents and double parking blockage. The developed system can provide a platform for users to search for empty car parking with ease and reduce the traffic issues such as illegal double parking especially in the urban area.

Keywords: *image detection, Internet of Things, mobile apps, motion tracking, smart parking*

1. Introduction

Nowadays, private vehicles increase rapidly throughout the years and parking has become a big problem everywhere. According to WHO, by 2017, majority of the population will be living in the city even for less developed countries [1]. Drivers find it harder to look for a parking lot at public parking areas with busy traffic flow in the city. This problem indirectly costing driver’s time and fuel just to find a vacant parking lots [2, 3]. Also, there are other problems occur due to the unmanaged parking system. For instance, Cyberjaya is currently facing problems such as double parking because lack of parking spaces and enforcement manpower by the local council. Thus, it is crucial to have an automated system that can solve this teething problem happening everywhere [4-6].

There are quite a numbers of parking system available, however, they have their own limitations and disadvantages [7, 8]. For example, sensor based parking guidance system is only designed for indoor parking. This system is harder to be implemented as it need wirings to interconnect sensors and LED. Although there are numerous methods of detecting cars in a car park such as magnetic sensors [9-11], microwave radar [12-14] and ultrasonic sensors [15-17], they are costly to be installed at every parking lot. Thus, a more cost-effective solution is necessary to enable smart outdoor parking especially in urban area where most of the parking are on-street [18-20].

In contrast, implementation of parking system through digital image processing is cheaper as one camera installed at an area can detect outdoor empty parking lots for a wide area [21-25]. The image processing is completed by capturing image frames in real time for parking vacancy detection. Camera based systems can be divided into three categories: vehicle-driven, space-driven and mixed methods. The proposed method is vehicle-driven where

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vehicle motion is the major target. Blob tracking method and Canny edge detection method are used for vehicle detection.

IoT (Internet of Things) Smart Car Parking System Using Machine Vision is the promising solution to improve the current situation. This system consists of IoT, mobile application together with machine vision through digital image processing. Ubidot is used as the database to store data collected from Pi at the same time allows mobile app, Spot to download the real-time data upon request. On the other hand, Firebase is used to enable user login and communication platform data storage.

All users are required to register to the application with their user name, email and car-plate number. If there are any emergency incident such as user forget to switch off the headlight, children left in locked car or suspicious people trying to break in the car, other users can use the mobile application to alert the driver using chat feature in the application. Besides, with the mobile application, drivers can communicate with other user if their car is double parked by other user. This system reduces the time for drivers to find parking and resolves the double parking problem.

2. Research Method

The smart parking system consists of two major parts which are car park monitoring and Android mobile application. Figure 1 shows the block diagram of the system. The proposed method to monitor the outdoor parking space is by using a camera placed on top of nearby building, and real-time video will be captured and processed. After image processing, the real-time data of the car park will be collected and send to online database for data storage and monitoring. Next, the second major part of this project is the mobile application that retrieves data from database and displays it to the user. Besides, another feature of the application is to allow users to communicate with each other in the event of emergency incidents. User can contact the driver by either scan the QR code or insert the car plate number. Double parking issue therefore can be effectively handled if the drivers can be contacted to move their car using this application.

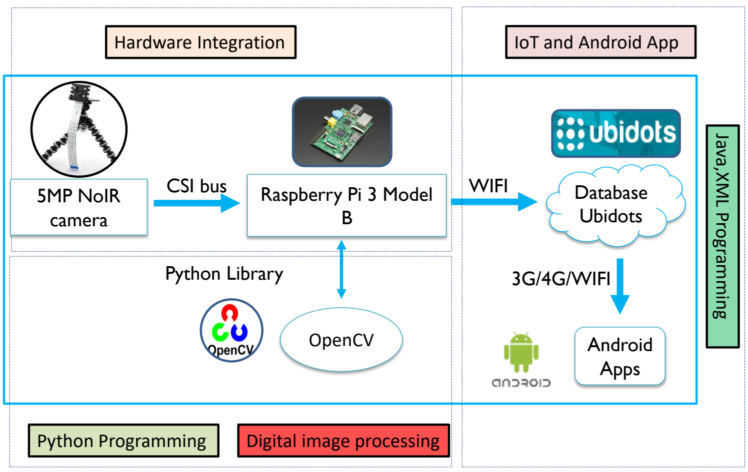


Figure 1. Block diagram of the proposed system

2.1. Principle of Detection

Vehicle body consists different shapes, edges and colors. Numerous car components like windows, hood, bumper, headlight, front grille, and license plate contain more edges compared to normal road condition without the presence of the car. Surface of the parking lots, except the white mark-off lines, is more uniform and less edges relatively. Thus, it is safely assure all vehicles can be distinguished from road surface or empty parking lots by detecting the edges of the vehicles. Besides the above reasoning, commonly the moving objects in the parking space are pedestrians and vehicles, thus assumption of larger moving objects exist in the parking space belongs to the vehicles is logical. Tracking moving vehicles enter or exit the parking, followed by detecting the edges within the parking lots can significantly improve the detection accuracy.

Once the position of the camera fixed, all the parking lots coordinates are known and segmented. To reduce potential environmental factors that may contribute to error in detection, a black overlay is masked on top of the video frames to block the surroundings such as trees and road. Canny edges detection technique is utilized to focus on all the edges of the segmented frames. The edges of the frame are converted into white pixel while the others are black in colors. Afterward, the image is dilated to enlarge and increase the white pixels in the image. Dilation is one of the morphological operation useful to combine multiples small objects into a larger blob. As the result, when the vehicles present in the parking lots, more edges contribute to large amount of white pixels. The percentage of white pixels in the segmented image is calculated based on the (1).

$$\% \text{ of white pixels} = \frac{\text{total white pixels}}{\text{total segmented image pixel}} \quad (1)$$

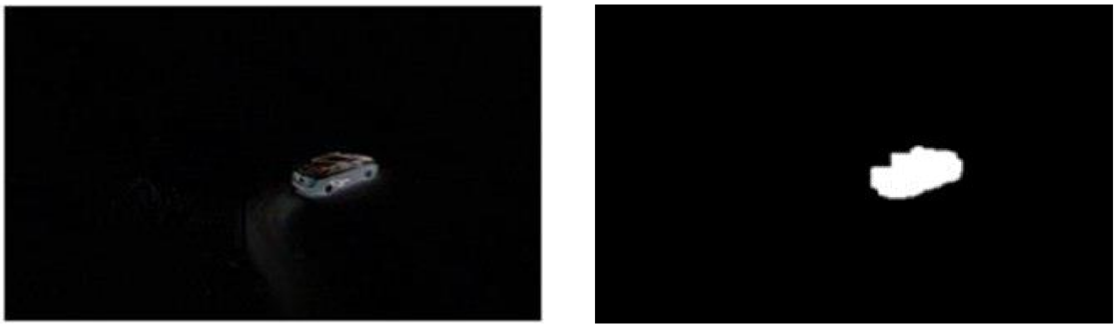
All the percentage results of all segmented parking lots are then stored in the program and repeatedly refresh to the latest result. The resulted image shows edge in white pixels while the background in black. Higher percentage of white pixel appear in the segmented frame allows us to determine the car presences in it. Figure 2 shows the image after Canny edge detection.

Figure 2. Image after Canny edge detection

Next, second step is to detect the moving vehicles in the parking space. The video input frame captured is first converted into greyscale to remove all the colors, followed by Gaussian smoothing applied on the image for filtering purpose. Blob detection technique is used in this project, image subtraction between video frames in greyscale to find the differences. After subtraction, image is binarized to convert the image to black and white with a fixed threshold. The differences between the frames are turned into white color, at the same time static background becomes black in color. To signify and enlarge the potential vehicles blob, dilate operation is utilized. As a result, all the moving objects in the captured view are white blobs.

Then, by specifying the area size of the objects, the unwanted noise such as pedestrian can be filtered out to focus on the moving vehicles that enter or exit the parking space. Once noise is filtered out, the centroid of the blob is determined and a rectangle box is drawn on the moving vehicles. The centroid location is used to detect the transition happened in which exact parking lot. Figure 3 (a) shows the image result after subtraction and Figure 3 (b) shows the image result after dilation. As the blob, vehicle in this case is moving, its centroid is consistently updated to the latest coordinates. After the transition of vehicle entering or exiting the parking lot is completed, the last centroid position will identify the exact transition happened in which segmented parking lot. Then, the corresponding parking lot will go through Canny edge detection process again to obtain the latest result of total white pixel percentage using the same (1).

Finally, by comparing the latest percentage to the stored percentage, the differentiation between exit or enter the parking is possible. For instant, if the transition happened is vehicle entering the parking lot, the latest percentage will be significantly higher than the stored percentage, because the stored percentage value is extracted from empty parking lot before the vehicle enters. Using this logical approach, the program can identify that this is indeed an incoming transition of vehicle enters the parking lot. This logic also works well for vehicle exiting the parking, as the stored percentage will be higher than the latest percentage.



(a) (b)

Figure 3. Image after (a) subtraction and (b) dilation

2.2. Implementation

An outdoor parking space consists of 20 parking lots is selected for prototype experiment. The camera is placed at the 5th floor of nearby building to enable bird view to the parking space. In this prototype, Raspberry Pi 3 Model B is used as the main computer to receive the input from camera as well as a processing unit to process the video data. The camera selected is 5MP NoIR camera with 0.67x wide lens installed, connected to Raspberry Pi 3 Model B via CSI data bus. The camera is installed on top of a small tripod to ensure static position when capturing the video.

After the hardware is setup, the video data will be processed using OpenCV built-in libraries. Figure 4 shows the flow of the image processing of the system. The image processing algorithm is written in Python languages in Raspberry Pi 3. Raspberry Pi 3 is powered via microUSB with the standard power supply of 5.25V, 2A. Internet connection will be established via WIFI to allow data uploading onto online IoT database, Ubidots. Once the position of the camera is fixed, all the parking lots coordinates are known and segmented. To reduce potential environmental factors that may contribute to error in detection, a black overlay is masked on top of the video frames to block the surroundings such as trees and road. The experiment data is collected for 5 days during day time, 4 of the 5 days are good weather with clear skies, and 1 rainy day. The video captured is resized to resolution of 500 x 500 in order to achieve smoother video performance without compromising the detection accuracy.

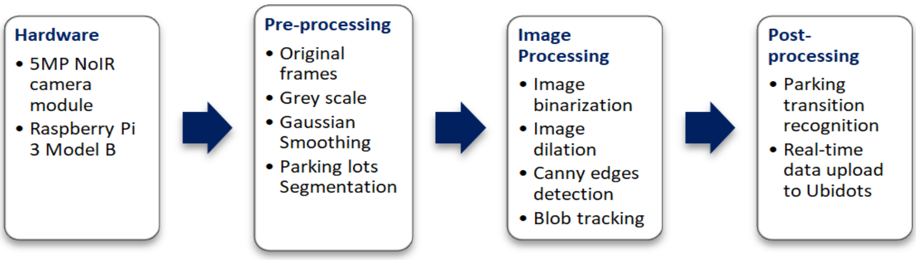


Figure 4. General flow of the image processing of the system

2.3. Database and Android Mobile Application

Ubidots is used as the IoT database for this project, it is one of the growing IoT online platform designed to store all the data uploaded from IoT devices. Data uploaded from Raspberry Pi is stored and displayed on Ubidots. Then, the data can be downloaded to Android mobile application whenever user intents to observe the available parking space. Spot also allows user to sign up and login, thus Firebase is utilized as backend online database to store user data as well as support mini chat room feature built-in in the application. Firebase is a mobile and web application platform with tools and infrastructure designed to help developers build high-quality apps. Firebase is made up of complementary features that developers can mix-and-match to fit their needs. Since this project is just prototyping, we only use free version for both platforms.

Android mobile application is designed to allow user to receive the real-time parking space data whenever necessary. The mobile application is created using Android Studio and coded in Java and XML. Java is programming language to provide logic behind the application while XML language is used to design application layout. To observe the availability of the parking space in, user first access to Google Map with a location search bar option to find the nearest parking to their location. User can insert their desired destination on the search bar then Geocoder will suggest few locations for the user to select. Once the location has been selected, the nearby parking with camera installed will be displayed on the map. Then, the user can click in it and the application will navigate the user to the next layout showing the real-time availability of the parking space. When users register to Spot, they are required to provide their car plate number as one of their identity to other user. Second feature of the mobile application allows user to insert the car plate in order to start an instant chat conversation with the driver in the event of emergency or double parking. A chat room will be created for the two drivers to communicate.

3. Results and Discussion

The project experiment is conducted at one of the outdoor parking space that consists of 20 parking lots. The raw image of the camera view is shown in Figure 5. This image contains more redness due to the lack of infrared filter, however this NoIR camera is used since it has a better performance during low light condition. The image frame was resized to 500×500 resolutions and the frames per second of the captured video was maintained at 6 fps. In order to avoid any unwanted noises and false detection, a black mask was overlay on top of the raw input frame in order to cover the surrounding environments and the roads. Each of the parking space had been segmented with the dedicated coordinates of its own, so that the program could precisely identified the exact parking space that vehicle is entering or exiting from. Figures 6 (a) and (b) respectively show the motion detection during vehicle entering and after vehicle exiting at a selected parking lot (shows by a rectangular box) for demonstration purpose. The robustness of the program algorithm has been tested with several images that contain other moving objects such as walking pedestrians, bicycle etc. It has been confirmed that any changes in surrounding would not affect the performance of the system.

Figure 5. Camera view of parking space

(a)

(b)

Figure 6. Detection of (a) occupied parking lot when entering and (b) empty parking lot when exiting

3.1. Experimental Result

The experiment had been carried out for five days with different weather situation as the variables to test the system accuracy. Figure 7 shows several images captured by the camera in different day time. Green circles indicated empty parking spaces while red circles indicated occupied ones. Whenever transition happened, the circles would turned colour based on the latest status predicted by the algorithm.

Results of the experiments are tabulated in Table 1. The (2) is used to determine the accuracy. The overall detection accuracy is 96.40% for the total of 111 samples collected.The detection mistakes were caused by dimmer surroundings light due to cloudy or rainy weather. During lower light condition, instead of forming a large blob, moving vehicles may formed by several smaller blobs instead. Then, the program may potentially miss out any moving vehicles in the parking space, because the smaller blobs will be recognized as noise and filtered out. The mistakes however can be reduced by adding luminance detection when capturing the images. By sensing the light intensity of the video, the program can be built to switch the dilation iterations. For lower light conditions, more iterations are preferred to improve the accuracy.

$$\text{Accuracy} = \frac{\text{Correct Predicted Transition}}{\text{Actual Transition}} \times 100\% \tag{2}$$

Over 96.40% accuracy with smaller number of samples collected proven that this parking detection method is working well and it is also easily scalable and low cost. With more advanced camera and computer installed, it certainly can further improve the detection accuracy.

Table 1. Data Collected from 111 samples

Day	Weather	Number of sample of transitions	Detection accuracy (%)
1	Clear	15	100
2	Clear	37	100
3	Clear	20	95
4	Rain	24	91.67
5	Clear	15	93.33
	Total	111	96.4

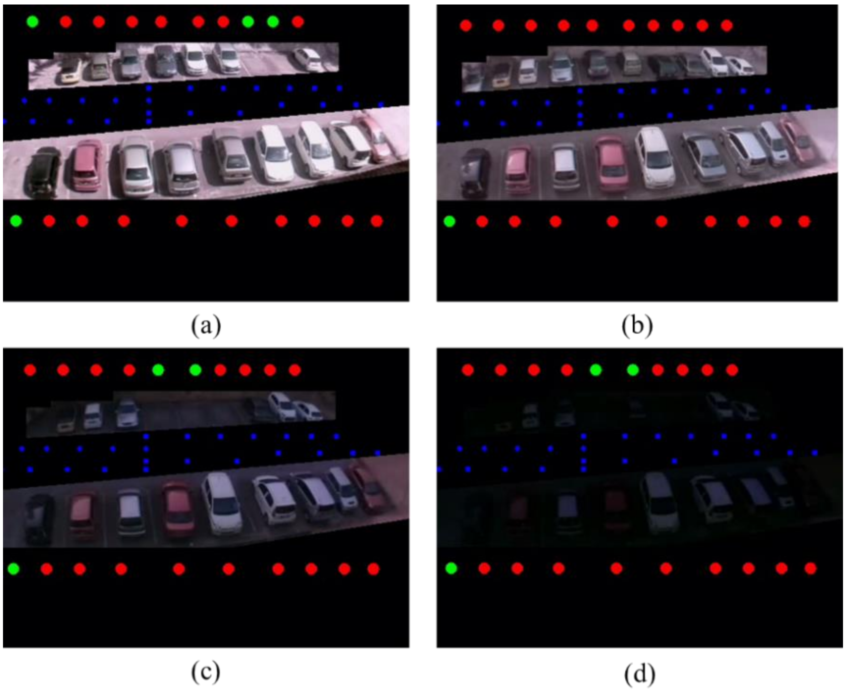


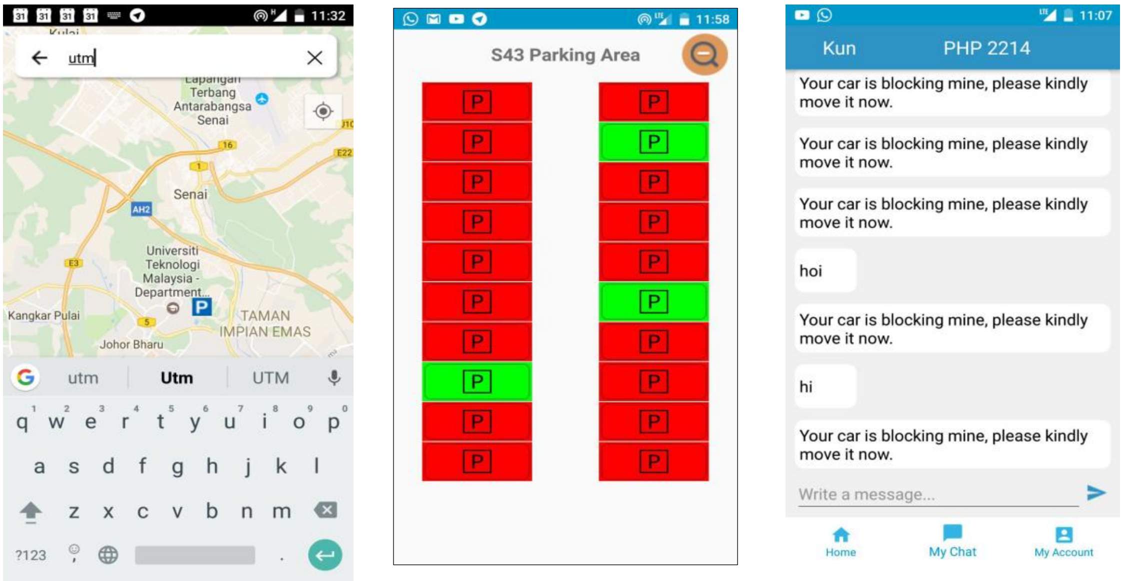
Figure 7. Detection image during (a) noon (b) afternoon (c) evening (d) night

3.2. Online Database

The data uploaded from Raspberry Pi 3 can be displayed on Ubidots website. Two main data are uploaded into the database; the total number of parking and the 20 parking lots status encoded from binary form into decimal form. From here, monitoring by private owner or related authority is possible as the data is useful to create statistics to better understand on how public uses the parking space. Once the system operated in 24 hours, the real time data can be collected and display on this dashboard in various format such as bar chart or table. In the future, if this system is installed in a paid parking space, the owner can acquire more parking space related data and plan for the business strategy. The Firebase database also has a data structure where all the user info and chat are stored inside.

3.3. Android Mobile Application

An Android mobile application is created in order for user to retrieve data in real time. When user click into the application, it will first navigate the user to a Google Maps layout as shown in Figure 8 (a). A search bar is located on top of the map for user to search for their desired destination. Then, several parking area will be suggested or list out from the input text, so user can select their preferred parking area. Once the selection is completed, the map will automatically moves from the current view to the selected place with a map pin showing the location. From here, user can observe if there is any nearby parking space with the parking logo. The parking logo indicates that the parking is installed with the camera providing the real time data on the availability of the parking space. Next, user can click on one of the parking logo and the mobile application will navigate the user to another page showing the current status of the parking space, as shown in Figure 8 (b). The parking status are showing in two colors, red and green. Red indicates that currently the parking lots are been occupied while the green color parking lots are the available empty lots. From here, user can actually plan ahead of their journey by first observing actually how many parking are available. Beside, Figure 8 (c) shows the instant messaging features in the mobile application, users can start conversation with each other to resolve emergency situation.



(a) (b) (c)

Figure 8. (a) Google Maps layout, (b) Real time parking status layout, and (c) Chat room layout

4. Conclusion

A cost effective method of smart parking system is proposed and implemented using camera to detect the presence of vehicles in the parking lots and Raspberry Pi as the microcontroller. Due to the lightweight of the hardware used in this system, it can be installed in various locations to obtain the best view angle to the parking space. This system is scalable and suitable to be installed around the city to construct a network of smart parking system, contributing in building a smarter city.This system been tested on an actual outdoor parking space, with diverse weather conditions such as clear sky and rain. The detection accuracy obtained is 96.40%, which suggested that this method is effective. Nonetheless, night time detection can potentially achieves the same accuracy with sufficient night illumination. In the future, the accuracy of this method can be further improved by using better camera and faster processing unit. This system also uses internet connection to upload the real-time data, aligns with the vision of smarter city when more sensor devices connecting to the internet, create a network of Internet of Things. Finally, the mobile application can potentially be commercialize and provide on Google Play store for public to download and free to use, allow public to access to the real time parking status.

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