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IMPLEMENTATION OF SMART PARKING SYSTEM WITH REAL TIME MONITORING

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Abstract

The increasing number of vehicles leads to high demand for parking space. Finding one available space in large parking area can be difficult for the driver. In many cases occurring nowadays are, the driver often finds no space available, even after wasting time searching. The worst case is the driver cannot monitor the parked vehicle. Moreover, recently the nature of the parking area can raise the probability of a crime. This paper proposes a smart parking system, in which drivers can view, select, and reserve an available parking space before arriving at the parking area. Reservation in advanc saves 3-5 seconds, which will reduce the queues at the gate. CCTV cameras are used to monitor the parking area and accessible for the driver, with the proposed system enables the driver to own the certainty for having available parking space before arriving at the destination, to park in the space less than the usual required time, to monitor the parked vehicle as the driver can simply open the website and access the available CCTV camera. The dedicated CCTV network produces less than 300ms of video streaming that provides real time monitoring for the user.

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1. Introduction

Previously when there were still fewer cars on the streets, it was easier to find a parking space available at the place or near the place of activity. In addition, the drivers could easily monitor their cars. Therefore, when something urgent happened, the driver could get to the place quickly. The automotive industry boomed, where cars were produced in a great number making the prices of cars became cheaper and more affordable. Prosperity began to rise, and more people bought cars (Figure 1). As a result, more people use their private cars instead of public transportations and more parking spaces required. People often park the vehicle far from the place of activities, due to the limited parking space. Entering the parking area will not guarantee that the driver gets the space. A research showed that 86% of the drivers still had difficulties to find one empty space after entering a space building [1].

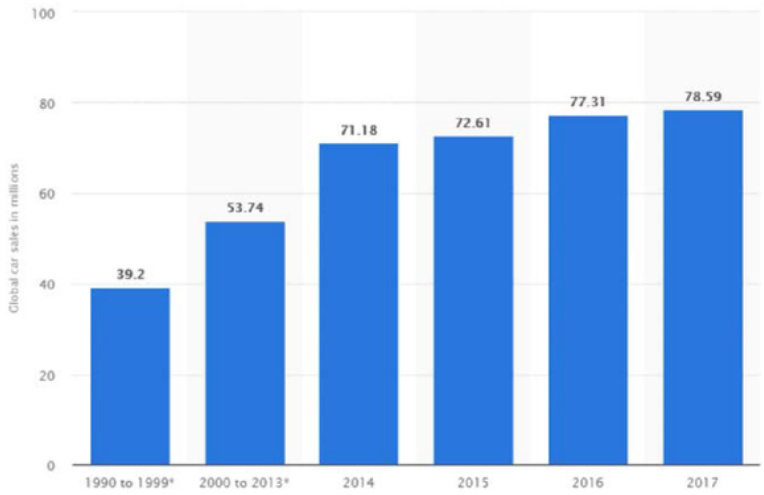

Figure 1. Number of cars sold worldwide from 1990 to 2017 (in million units) [2].

Many local governments have their own regulation regarding parking space. Commercial facilities, for example, must provide enough parking spaces for their customers. Hong Kong government dictates that to match manifest operational requirements, commercial facilities should have 'sufficient on-site parking' [3]. In Houston, supermarket or convenience market should have five spaces per 1,000 ft^2 (about 93 m^2) Gross Floor Area (GFA) of the building [4]. Meanwhile, Northern Ireland authority requires food retail shops should have one space per 14 m^2 GFA, and minimum recommended space for a car is 4.8 m by 2.4 m [5]. In some cases, the required parking area can be almost as big as the GFA of the building itself. The road parking area can be used as the temporary solution when parking area becomes overflowed, but this sacrifices the space for the road, and in most cases, causes congestion [6-8].

Nowadays, parking area becomes bigger and more difficult to be monitored. In addition, the bigger parking area also needs more resources to maintain. The location and the design of the parking area makes it hard, even for the parking management to monitor. This condition also makes it difficult, if not impossible, for the owner of the cars to monitor their cars all the time. While most of the people will be concentrated at the center of activities, such as office buildings or shopping centers, only a few people will be in the parking areas. This will increase the probability for a person isolated and targeted for crime. Parking areas are open for public, and everyone can possibly have criminal intention [9]. In addition, they might attract people with criminal intention as the parked cars and uneven lightning provide the ideal place to hide.

An assessment is needed to determine the security of a parking area as it measures the vulnerability by determining threats exist against the current security system. The assessment then answers whether parking management should provide the reasonable security system for their service. The security system should have a psychological effect on a potential criminal, discourage potential criminal for committing crime. This can be achieved by adequate lighting, the presence of CCTV, security guards, and signs installation

indicating the presence of the security system. In addition, it should be preventative which enables to stop the potential acts of criminals physically. It includes the use of barrier gate and mechanism to prevent unauthorized access entering the site [10]. Security can be active or passive. Active security involves direct human involvement and the use of specific equipment (such as security guard and CCTV); meanwhile, passive security requires the design of the physical part of the facility to psychologically obstruct potential crime. This concept is known as Crime Prevention through Environmental Design (CPTED) [11]. CPTED is designed for parking area includes lightning, surveillance, access controls, sign and graphics, natural territorial reinforcement, maintenance of the area, and supported by legitimate activity [9, 10, 12].

In previous research, the determined sensors were found to detect vehicle at a parking space [13], and design a parking reservation system [14]. Thus, the objective of present study is to present a parking system, which allows the drivers to search and reserve an empty space before entering the parking area, and to monitor the vehicle during parking.

This paper is organized as follows: Section 1 explains the condition of parking services and difficulties for a driver to get a space and monitor the car. Section 2 discusses the architecture of the proposed system. Section 3, 4, and 5 discuss scenarios of the system. Section 6 discusses implementation of the system. Finally, the last two sections offer discussion of the current research and conclusion.

2. System Architecture

The proposed system consists of five modules: mobile reservation, parking gate, parking sensor, CCTV, and power. The detailed system architecture is shown in Figure 2.

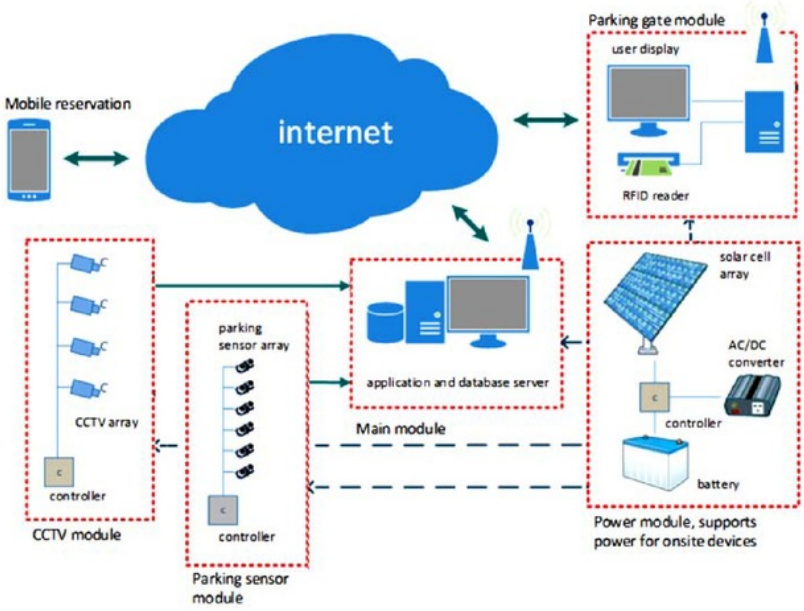

Figure 2. System architecture.

Based on Figure 2, mobile reservation module contains application to view, to select and to reserve a parking space. Meanwhile, the parking gate module performs access control, for incoming and outgoing cars. A driver can also view, select and reserve a parking space at the parking gate module. Then, the parking sensor module is located in each space and detects the presence of the car. In addition, CCTV module provides monitoring for the whole area, and accessible by the parking driver. Then, the power module uses solar panels to provide alternative electricity for the system. From Figure 2, it is clearly shown that the whole module is controlled by the main module, which contains the application and the parking database. Each module is discussed as follows.

First, the parking gate module provides on-site reservation for the driver. The RFID reader is located at the parking area's entry gate will be as the place for reserving parking ticket when the driver tap his/her RFID card. When the driver chooses a parking space, his ID from RFID and the space ID

is recorded. The parking gate module uses a NodeMCU with embedded Wi-Fi, provides wireless connectivity with the main module. The pre-registered driver can also view, select and reserve a parking space using an application installed in the mobile device. The reservation will make sure the driver gets a parking space when he/she arrives at the parking area.

Second, the parking sensor module is installed on the floor of every space [15]. This module consists of an ultrasonic sensor, a microcontroller and an array of LEDs. The module uses HC-SR04 ultrasonic sensor, and placed at 90° angle. The sensor detects the presence of a vehicle and updates the status of each parking space to apply in the main module. A NodeMCU, embedded with an ESP8266 Wi-Fi SoC (System on Chip) is used as the microcontroller. The array of LEDs is connected to the controller display visual information whether the space is available or occupied. Then, CCTV cameras are used to monitor the parking area. The use of CCTV can reduce, but not eliminate the security personnel. CCTVs can record events in the area, which can be used as an evidence when needed. Each CCTV is mapped to cover certain space. A sign indicates the presence of CCTV is placed within the area to discourage potential criminal and creating secure feeling for the parking easier. More about access control to the CCTV will be discussed in surveillance scenario.

To provide alternative power also used as backup power, the system uses three, 100Wp solar panel. With five hours of average sunlight, the panels generate a total of 1,500Wh. The panels are connected to two 100Ah, 12V batteries, providing 2,400Wh energy. Solar panels are installed facing true north. The panels are tilted at 6.066°. The angle is calculated using the following rules [16]:

- If the latitude is below 25°, latitude times 0.87.
- If the latitude is between 25° and 50°, latitude times 0.76, plus 3.1 degrees.

Location of the panel is -6.972745, 107.632705, so the optimum angle obtained at $6.972745 \times 0.87 = 6.066°$.

Lastly, the main module consists of a server hosting web server and database server. The status of parking space and reservation request will be processed and stored in this module. The technical specification for this module is detailed in Table 1.

Table 1. Main server specification

Processor	Core i5 7500
RAM	8GB
HDD	1TB
Operating System	Ubuntu 16.04
Web Server	Apache2
Database	MySQL
Programming	PHP7
Other	Mikrotik Router Management Tool

3. Access Control

All parking service users entering the area are given an RFID card, which is used to open the barrier at the gate. The RFID also contains the parking ID corresponding to the physical location of the space. Pre-registered user with mobile device link these ID to the device MAC address. For a subscriber, the driver can register their employee cards, as long as they use RFID technology. All space in the parking area can be pre-mapped or randomly assigned to the employee and guests. Either way, the system can identify which car parks at specific parking space.

4. Reservation

When the driver reserves the space, the system begins to countdown. The driver must arrive at the gate to tap the RFID card before the countdown ends. If the driver fails to do so, the reservation is revoked and he must choose another space at the parking gate. Otherwise, another countdown begins to make sure the driver occupies the space. When in reserved status, the space cannot be chosen by another driver. The detail is illustrated in Figure 3.

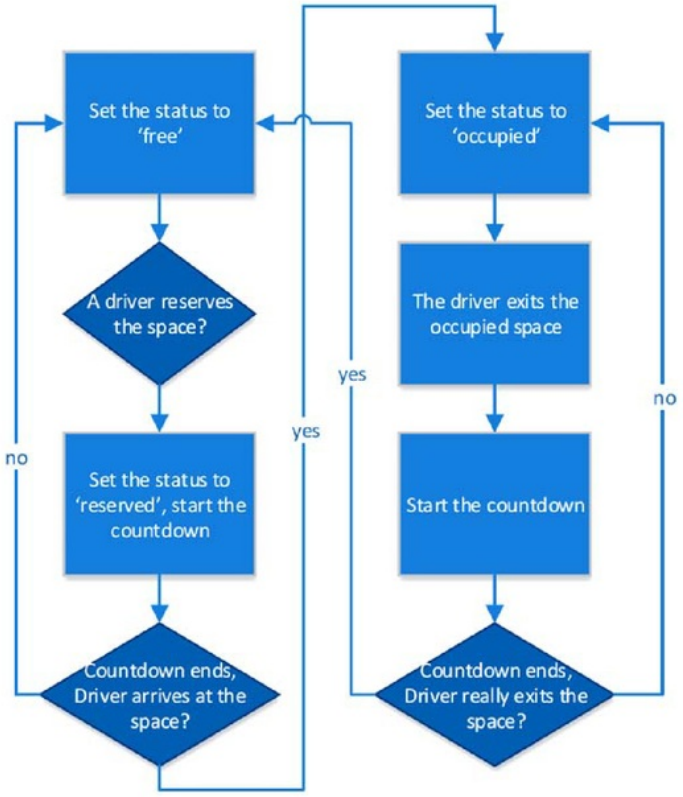

Figure 3. Reservation flow diagram.

If the car arrives at the space within the specific time, the parking sensor module triggers the system to change the status from reserved to occupy. When the car leaves the space, the parking sensor triggers the system to start another countdown, to make sure the leaving car exits the space properly. If the car does not enter the space again within specific time, the system change the status from occupied to free, so the space can be reserved by another driver immediately. The overall parking scenario is illustrated in Figure 4.

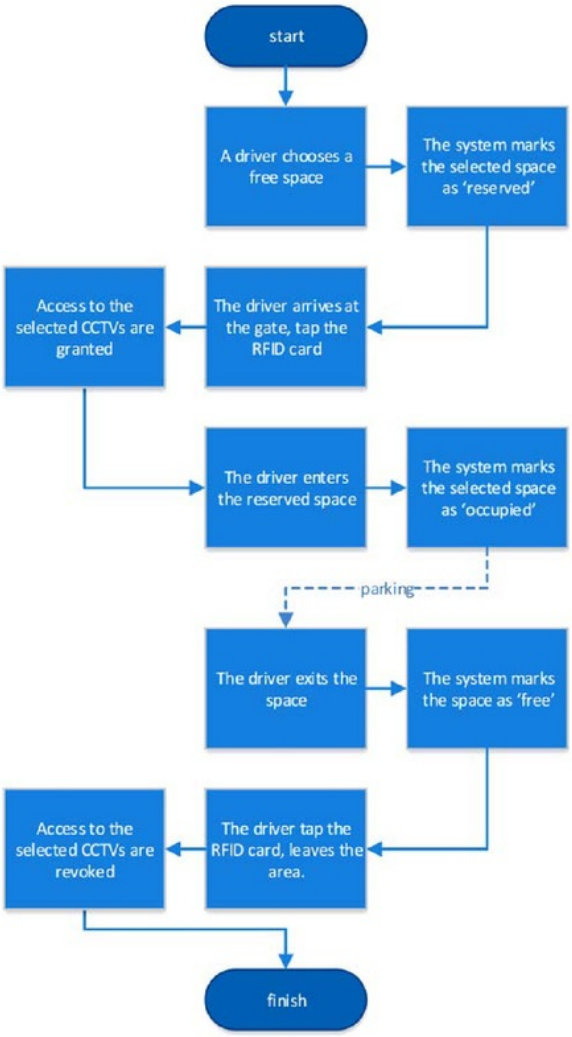

Figure 4. Parking scenario.

5. Monitoring

CCTV monitoring is available for the parking management. To access the monitoring service, registered users access the web using the registered

mobile device (Figure 5). Access to the CCTV can be restricted to a certain point, which means drivers can only access some of the CCTV showing only their own cars. Accessing all CCTV should be forbidden because this privilege can be misused. The driver should have limited access to the CCTV, but enough access to have the secure feeling. When the space is reserved, the driver can access the CCTV corresponding to the space. All access to the CCTV will be revoked after the driver exits the parking area.

Figure 5. CCTV monitoring for parking management (left); driver (right).

6. System Implementation

The proposed system was tested in our campus parking area. This area consists of 41 parking spaces, with 33 perpendicular parking spaces and eight parallel parking spaces. The floor plan is shown in Figure 6.

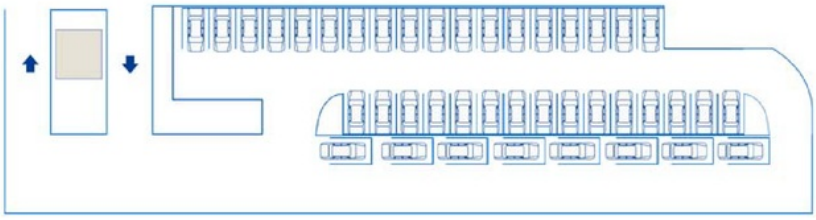

Figure 6. Parking area floor plan.

Average time for RFID card detection is 33ms. After the card is detected, information about the driver and the parking location will be shown on the

monitor. A 3.5 seconds delay is added to display the information. If the driver reserves in advance using the mobile device, it will eliminate the time needed to choose the available space at the gate. From the experiment, it will cost additional three to five seconds per driver. The countdown time for the driver to tap the RFID card to occupy the parking space is set to five minutes. There are three CCTVs covering the whole parking area. Each CCTV can be accessed by the driver parking at the corresponding location, showing his car.

7. Discussion

The result of the study can be used as the reference for the further implementation of the system. While this scenario can reduce personnel needed, we found some issues regarding the implementation. These issues are mostly caused by the driver's personality. The sensor detects if a car enters a parking space, but it cannot detect whether it is the assigned vehicle or not. To solve this problem, additional smart barrier is needed (Figure 7). This device can be controlled individually through RFID or mobile phone [17], and it can identify the RFID card of the driver. However, this device costs US$30-60 per unit.

Figure 7. Smart barrier.

Another alternative is adding an RFID reader module at every parking space. This reader costs about US$3 each. When a car enters the space, the driver must tag his/her RFID within a specific time. The system then decides if the ID is matched to the space. Alarm or buzzer can be used as the warning if the driver is parked in the wrong space.

Reservation in advance before the driver arrives at the gate will save 3-5 second. In rush hour, it will cause significant queue and potentially caused a congestion. In the future, parking management should enforce driver to have the reservation before entering the parking space. To prevent loss when the driver is failed to occupy the space (by accident or intentionally), the system can charge the driver for a specific amount of money. If the car exits the space but with no intention to leave, the sensor might be triggered. Then, the delay mechanism is introduced to prevent such false reading. Average time for the driver to park in the space is around three minutes. It was measured from the moment the driver tapped the RFID card.

Access to CCTV should be limited to (1) the nearest CCTV which shows the driver's vehicle, (2) the path from the entry gate to the reserved space, and (3) the path from the reserved space to the exit gate. While this access is limited, it should provide enough security feeling for the driver.

From the experiment, overall queue time can be reduced by eliminating reservation process for drop off vehicle. Still, they should get the RFID card at the entry gate, but only for identification purpose. Therefore, this kind of driver should be restricted to access the CCTV. Using the dedicated network for the CCTVs drastically reduce monitoring delay. The CCTV stream delay was below 300ms in average, fast enough for the user to feel they are interacting spontaneously with the system [18].

8. Conclusion

The system provides certainty for the driver to have parking space before entering the area, and to eliminate time wasted to find an empty space. The RFID card is used to identify the driver, vehicle and parking location at a certain time. This will provide detailed records for security purpose. All

modules connected wirelessly, providing easy and convenient for the installation and maintenance. Using the location and the driver data, the driver can monitor his/her vehicle by connecting to certain CCTV cameras. Minimum video stream delay of less than 300ms from the CCTVs provides real time monitoring of the vehicle.

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