Smart Parking System (SPS) Architecture Using Ultrasonic Detector

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Abstract

With the increase in vehicle production and world population, more and more parking spaces and facilities are required. In this paper a new parking system called Smart Parking System (SPS) is proposed to assist drivers to find vacant spaces in a car park in a shorter time. The new system uses ultrasonic (ultrasound) sensors to detect either car park occupancy or improper parking actions. Different detection technologies are reviewed and compared to determine the best technology for developing SPS. Features of SPS include vacant parking space detection, detection of improper parking, display of available parking spaces, and directional indicators toward vacant parking spaces, payment facilities and different types of parking spaces (vacant, occupied, reserved and handicapped) through the use of specific LEDs. This paper also describes the use of an SPS system from the entrance into a parking lot until the finding of a vacant parking space. The system is designed for a four-level parking lot with 100 parking spaces and five aisles on each floor. The system architecture defines the essential design features such as location of sensors, required number of sensors and LEDs for each level, and indoor and outdoor display boards.

Keywords: *SPS, Ultrasonic sensors, Car park, Improper parking Directional signage*

1. Introduction

Time and cost are two important factors of human life, whether for an individual or a business. As quality of life increases, more and more people are inhabiting cities. Urban life requires centralized public facilities. Shopping complexes are an important point of interest both for a city's inhabitants as well as for visitors. With the emergence of modern shopping complexes which provide a variety of services, more and more people are attracted to visit them. Hence, more shop owners prefer to locate their business in shopping complexes to target more customers and increase revenue [1].

Recently, shopping complexes have begun providing services much more diverse than just pure selling and buying. Customers can use banking services, post offices, food courts, cinemas, children's play areas, and so on. The growth of shopping malls has influenced shopping culture and behavior. For instance, in Malaysia window-shopping, or visiting shopping complexes simply for looking rather than buying, is a common activity [2].

Providing sufficient parking for visitors is one of the main issues in developing shopping complexes. Offering safe and secure parking lots with a sufficient number of spaces and paying attention to handicapped drivers are a few of the factors which can increase customer loyalty and attract customers to visit a shopping mall more frequently. Among the various types of parking lots are multilevel parking, roadside, roadside with ticket and barrier gate and roadside with parking meter; of these, the multilevel parking lot is the most preferred by patrons [3]. Safety, weather conditions, proximity and car park fees respectively are the main factors by which patrons choose a specific parking lot. Hence, multilevel parking lots are preferred, and for this reason were selected as the parking lot type for this study. SPS detects car park occupancy through ultrasonic sensors which are located above each parking space. Vacant, occupied, handicapped or reserved spaces are indicated by different colors of LEDs. "Improper parking" is the situation in which one car is parked straddling two vacant spaces and occupies both. Detection of improper parking and providing directions to vacant spaces and payment facilities are other services offered by SPS.

The objectives of this study are to highlight parking lots' importance, indicate the difficulty drivers have in parking their vehicles at shopping complexes, propose an applicable solution to solve the aforementioned problems, and outline an SPS architecture design. This paper is organized as follows: the introduction details the importance of shopping complexes and parking lots. Part 2 discusses current parking lot problems and the difficulties that customers encounter in parking lots. Section 3 explains detection technology and compares ultrasonic sensors with other types of detectors. Section 4 gives a system overview and the features of SPS. Section 5 outlines SPS architecture and the devices required to implement it. Finally, the last section offers conclusions and discusses current research.

2. Statement of Parking Lot Problems

2.1. Difficulty in Finding Vacant Spaces

Quickly finding a vacant space in a multilevel parking lot is difficult if not impossible, especially on weekends or public holidays. One study showed that 86% of drivers face difficulty in finding a parking space in multilevel parking lots [3]. Finding spaces during weekends or public holidays can take more than 10 minutes for about 66% of visitors. Stadiums or shopping malls are crowded at peak periods, and difficulty in finding vacant slots at these places is a major problem for customers [4]. Insufficient car park spaces \ lead to traffic congestion and driver frustration [5].

2.2. Improper Parking

If a car is parked in such a way that it occupies two parking slots rather than one, this is called improper parking. Improper parking can happen when a driver is not careful about another driver's rights. Sometimes improper parking occurs when a driver parks on or a bit outside of the lines of a parking space. The driver may notice his improper parking after leaving his car, but may not be willing to unlock his car, restart it, and adjust it to be inside the lines. This matter annoys other drivers and most of the time a driver who wants to park in a small leftover slot will give up and feel frustrated. Figure1 presents an improper parking situation.

Figure 1. Improper Parking

2.3. Parking Fee Payment

Parking fee payment can be a time consuming activity for people. Since many current payment machines just accept small notes and coins, finding the exact amount and queuing for payment is not pleasant for drivers. Therefore, providing services that make payment convenient is desirable. One survey showed that queuing up for payment and finding coins for parking fee payment is troublesome. Moreover, most respondents agreed that using Touch'n'Go (a system that allows simply swiping a card and deduct fees from inside credit) is useful and will decrease queue up time[3].

3. Detection Technology Review

The choice of appropriate detection technology depends on the objective and scope of the project [6]. Two types of detection technology, vision-based and sensor-based, are discussed in this study. Vision-based methods use closed-circuit television (CCTV) — usually one camera is responsible for more than one parking space — and image processing software to detect parking space status. Sensor-based methods use one sensor for each individual parking space.

3.1. Vision-Based Method

Monitoring parking lot vacancy is a significant technology which can be used for guiding cars to vacant spaces and for efficient use of parking spaces. Monitoring detection technology can be divided into two categories. The first estimates the number of remaining vacant spaces for the entire parking lot by counting incoming and outgoing vehicles. The second monitors the status of each individual space and can be used to guide a car to a vacant space. To help drivers find a vacant parking space without much effort, intelligent parking systems should provide the specific location of vacant spaces and not just the total number of spaces [7]. To detect the status of an individual parking space different methods have been utilized, such as ultrasonic sensors placed at each space (thus it requires many sensors), or surveillance cameras placed at a high position (allowing supervision of a wide area by a few cameras, which is more useful in outdoor parking lot) [6].

Detection methods based on cameras and image processing suffer from a lack of accuracy and can be affected by environmental or weather circumstances. Major problems of vision-based parking detection systems include shadow effects, occlusion effects, vacillation of lighting conditions and perspective distortion. Light-colored cars in strong sunlight might mislead detector software into detecting a full space as vacant; in the same way, a shadowed area may be mistakenly identified as a dark-colored vehicle, leading an empty space to be mistakenly seen as occupied. When the sun is blocked by a cloud, the change in lighting may also affect detection performance [7]. Variable light intensity is one of the major challenges in a camera-based detection system.

3.2. Sensor-Based Method

Another detection technology uses sensors to detect vacant spaces in a parking lot. With the availability of various types of sensors, selecting a suitable detection system is an important part of implementing a smart parking system. Different factors play a role in choosing the proper sensor, including size, reliability, adaptation to environmental changes, robustness and cost [8].

Sensors technologies are categorized as either intrusive or non-intrusive. Intrusive sensors need to be installed directly on the pavement surface, so digging and tunneling under the road surface are required. Magnetometers, pneumatic tubes, inductive loops, weight-in-motion sensors and piezoelectric cables are considered intrusive sensors[9]. Non-intrusive sensors only require fixing on the ceiling or on the ground. Ultrasonic sensors are categorized as non-intrusive sensors, meaning that they require simpler installation compared to intrusive sensors.

Ultrasonic sensors transmit sound waves between 25 kHz and 50 kHz. They use the reflected energy to analyze and detect the status of a parking space. Ultrasonic waves are emitted from the head of an ultrasonic vehicle detection sensor every 60 milliseconds, and the presence or absence of vehicles is determined by time differences between the emitted and received signals. Ultrasonic sensors can be used for counting vehicles and assessing the occupancy status of each parking space [10]. Despite the low cost and easy installation of ultrasonic sensors, they do have some disadvantages, particularly sensitivity to temperature changes and extreme air turbulence. Figure 2 shows how ultrasonic sensors work.

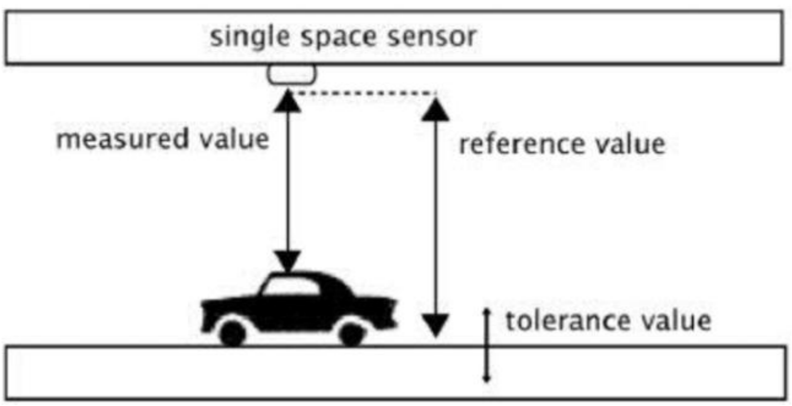

Figure 2. How an Ultrasonic Sensor Works [11]

4. Smart Parking System Description

4.1. SPS User Overview

In order to find vacant spaces, drivers look at an LED display board which shows how many and which type of vacant spaces are available at each level at that time. After navigating to the desired parking level, drivers look at internal signs hanging from the ceiling at the end of each aisle. Each internal sign shows two parts: the number of available spaces and the direction (left, right or forward) of the aisle which has a vacant space. Each individual parking space is equipped with LED lights which are located above the space and can show green, red, blue or yellow. The color indicates the status of that space: green means the space is vacant, red means the space is occupied, blue means the space is assigned for handicapped drivers and yellow means it has been booked or is a VIP or reserved space for specific reasons. When a driver enters a vacant space, the green light changes to red. Figure 3 shows the four steps of utilizing a car park guidance system.

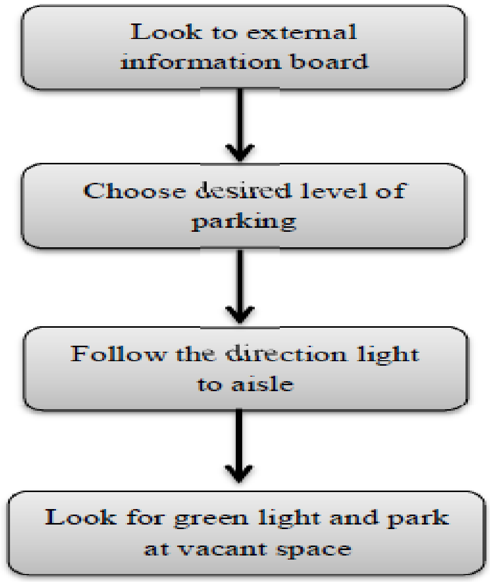

Figure 3. Overview of SPS Car Park Guidance System

4.2. SPS Technical Overview

Our proposed SPS detection system is based on ultrasonic sensors. For each individual car park, this would require one sensor fixed on the ceiling above each parking space. Ultrasonic sensors work based on echo-location. The sensor transmits a sound, which hits a solid object (car or ground) and is reflected back to the sensor. The time between the sent pulse and the returned echo is used to calculate distance. In a vacant space, the time between transmitted sound and reflection is longer than in an occupied space, hence the sensor can detect when a space is occupied. Figure 4 illustrates how it works.

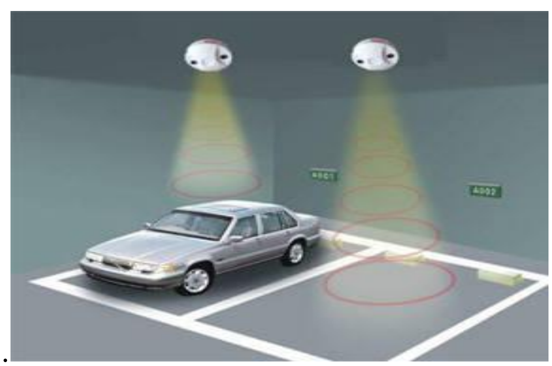

Figure 4. Ultrasonic Sensor Detection Area

LED lights can be attached to the detector sensor or mounted separately. SPS uses a separate LED indicator to be more flexible and make it possible to fix both pieces at the best position. The LED and the sensor connect to each other through a phone cable. When the indicator displays green, it means the parking space is available; when the indicator displays red, it means the space is occupied. In case of a handicapped parking space, a blue LED indicates vacancy and red indicates occupancy. Reserved spaces are identified by a yellow LED. Figure 5 shows two LED indicators, red and green.

Figure 5. LED Indicators

4.3. SPS Features

Smart Parking System (SPS) consists of main and secondary features for different purposes and situations. Some of the features mentioned in this paper will be part of future research. The main features of SPS are:

- Detect occupancy status of each individual space in a multilevel parking lot.
- Display the number of available spaces at entrance of parking lot, at entrance to each level, and at end of each aisle.
- Display directional signage for each aisle, showing drivers which direction has vacant spaces.
- Parking monitoring and management software to coordinate and operate the various features.
- Display different colored LED lights to differentiate between spaces (reserved, occupied, vacant or handicapped)
- Touch'n'Go module to facilitate payment of parking fees.
- Assign space beside each directional sign for advertising purposes.
- Line detection system to avoid improper parking.

Business logos are shown on the directional signage board, as shown in Figure 6.

Figure 6. Directional Board Advertisement

5. System Architecture

To develop the SPS architecture several pieces of equipment are required: ultrasonic sensors, LED indicators, indoor display boards, outdoor display board(s), zone control unit (ZCU), central control unit (CCU), network switch, telephone cable and management software. The ultrasonic detector transmits its status message through a phone cable to the zone control unit (ZCU), which collects and forwards the information to the central control unit (CCU) through Cat5 cables. The CCU processes the data and sends commands to the ZCU and LED panel. The ZCU is the middle layer of SPS and is responsible for controlling the ultrasonic detectors. Each ZCU manages a group of 40 to 60 ultrasonic detectors, sending the relevant information to the CCU. The ZCU connects through an RS-485 port to the indoor display board and ultrasonic sensors and communicates with the CCU through network switch and LAN connections. The CCU is responsible for the collection of parking space information and for processing data for the whole parking lot. The CCU transmits commands to the LED display board to update the parking space information. Simultaneously, collected data can be saved in the parking lot server's database which will allow a supervisor to monitor, manage and control parking lot information. Each CCU can support around 40 to 60 nodes, include ZCU(s) and outdoor display board(s). For a more efficient system, it is recommended that a maximum of 40 nodes be connected to each ZCU and each CCU. Figure 7 shows a prototype of a complete SPS.

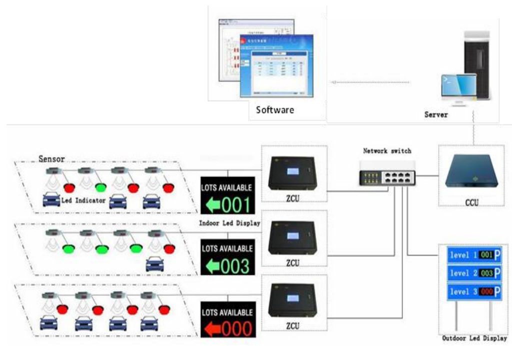

Figure 7. Prototype of SPS

In this paper, we assume a sample parking lot of four levels with 100 spaces on each floor. Each floor has five aisles. Figure 8 shows the position of sensors, indoor display boards, outdoor display boards, LED lights, ZCU and network switch at one level of the sample parking lot.

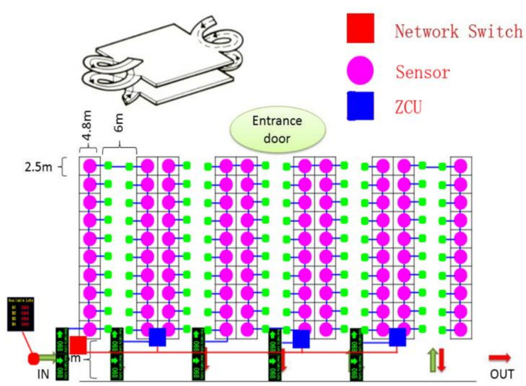

Figure 8. Position of SPS Hardware at One Level of Parking Lot

The line detection system, or improper parking detection system, consists of two extra sensors for each parking space, oriented horizontally along the lines demarcating the left and right boundaries of the space. If any car is parked on the line the sensor triggers an alarm and the driver should adjust his car within the lines until the beeping sound stops. Although some parking lots are using ultrasonic sensors and LED indicators at present, improper parking systems are not in place. Figure 9 presents how SPS's line detection feature works.

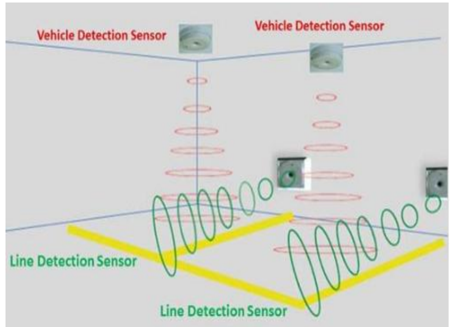

Figure 9. SPS Line Detection System Demo

6. Conclusion

The main contribution of this study is to introduce the most significant parking problem — i.e., finding an empty space — and propose a solution. Ultrasonic sensors can be used both for parking space detection and improper parking detection. The proposed architecture for a parking detection system would decrease searching time for vacant spaces and reduce instances of single cars improperly parking across two spaces. Future research might examine car park booking procedures and optimization of sensor usage. Cost effectiveness and marketing could be studied as well.

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