The Smart Parking System Using Ultrasonic Control Sensors

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Abstract. Over the past decade, the concept of smart cities has become very popular thanks to the Internet of Things (IoT) development and expansion for increasing the reliability of building the infrastructure of cities. The continuous increase of vehicles in the streets with the lack of car parking is becoming a problem in most urban cities. Therefore, the demand for smart car parking systems is increased for helping drivers to find a suitable car space quickly. This paper presents a smart parking system using infrared and ultrasonic sensors, which is controlled by Arduino Mega 2560. The Radio Frequency Identification (RFID) reader provides authorization to enter the smart parking system. On the other hand, a mobile application is added to allows users to know about the empty spaces based via WiFi application. This smart parking system is implementing in a small-scale model, and the results show that simulates the car parking with the mobile application, all the sensors, and the Liquid Crystal Display (LCD) screen display, to describe a view of the system architecture.

Keywords: Smart Parking, Internet of Things, Arduino Mega 2560, Ultrasonic, Infrared, RFID Reader, Node MCU 8266, JSON Database.

1. Introduction

Embedded systems are growing rapidly with the ability to provide high-speed information exchange between devices in communication systems. It has been one of the most common subjects of study since the 1960s. In the past ten years, the world has witnessed a technological revolution by access to Embedded systems and the Internet of Things (IoT) in many fields. This has reflected great development in our daily life qualities, services, and gives high efficiency [1]. Modern embedded systems are often based on microcontrollers. That is the reason why the embedded system is dedicated to specific tasks. Besides, design engineers can optimize embedded systems to reduce the size and cost of the product and increase the reliability and performance [2]. Recently, a lot of studies and researches on smart cities have been monitored with the expansion of the concept of the IoT, the widespread of what is known as the cloud, how to benefit from it in storing and sharing the data accurately and high quality, and creating the databases. Which made life easier and more civilized [3].

The IoT applications have a great impact on communication system everywhere. it can remotely operate and analyze data, as well as communicate with many around sensors devices and managed complex systems [4], via controlling them through mobile systems applications such as IOS, and Android [5]. One of the most important examples of the Internet of Things applications, smart parking, allow drivers to park their vehicle easily and quickly. It reduces traffic congestion and thus reduces
environmental pollution resulting from car exhaust [6]. The smart parking based on authorized access is proposed in this work, which allows entering parking via ID card working with the Radio Frequency Identification (RFID) device placed at the gate of parking [7]. In this work, all sensors are connected to the microcontroller using Arduino Mega 2560 to contains enough input/output pins. To send data, the number and location of empty places to the cloud, a Message Queuing Telemetry Transport protocol (MQTT) through the WiFi of the Nodemcu esp8266, have been used [8]. The mobile application has been implemented on the Android system to receive the data from the JavaScript Object Notation database (JSON), which stored in the cloud, which display all information on a screen to allow users park their vehicle easier and faster. This paper is organized as follows, introduction in section one, related work in section two, description of the equipment that was used in this work in section three, algorithm and operating system in section four, conclusion, future work, and finally acknowledgments.

2. Related work
In [9], proposed a Smart Parking System (SPS) that uses the techniques of Ultra-High Frequency (UHF) and the IEEE 802.15.4 wireless sensor network. This system has been integrated with customized software-enabled forms utilizing the collected information about the occupied state of parking spaces to direct the drivers to the nearest vacant parking spot. Furthermore, the authors used Google Cloud Messaging (GCM) in the central system to manage most of the alert events. While in [10], smart parking based on the Internet of Things (IoT) is a network architecture has implemented in the real world by T. N. PHAM and et al. In this real system, the authors used a novel algorithm that increases the performance of the current cloud-based smart parking system by helping users to automatically find a free parking space at the least cost. In [3], Ilhan Aydin and et al, suggested a new parking system. They develop small devices that use IoT technologies to send data through the Internet and by using a genetic algorithm the free parking space around the current location is found. In [11], A prototype of IoT based electronic parking system is proposed by Pampa Sadhukhan for quickly finding out some suitable parking slots for the cars. He used parking meter as an integrated component to address to provide smart parking management throughout the city. In [12] proposed using Arduino UNO in the tested prototype, to collect and send information into Raspberry Pi 3 by using the Bluetooth Low Energy communication technology. These data are periodically updated to the Backboneless cloud server via an internet connection, and this data using the Android application for finding free parking spaces. Finally, in [13], Sheetal N. Ghorpade, and Marco Zennaro, proposed a multi-purpose technique for localizing nodes to reduce the localization error by using the grey wolf optimization technique, they got better results compared with other algorithms, and the localization error is reduced up to 17%, the algorithm is efficient due to the selection of fast converging parameters.

This proposed system introduces a new design to collect the information as a real-time database of parking places in the cloud and the ability to know the location of those places and then send information to a mobile application to display to the users easily. by programming microcontroller Arduino Mega 2560 with ultrasonic sensor, this is the difference between the proposed system and the others parking systems. The detailed working process is explained in the next section.

3. Description of equipment
In this section the equipment that is used in this work includes are considered:

3.1 Arduino Mega 2560
It's an open-source physical measure description based on a direct microcontroller board that includes an ATmega328 microcontroller and an improved environrment for writing software for the board. Arduino is used to connecting and communicating between various devices [14]. Arduino Mega 2560 is one of the most famous boards for microcontrollers ATmega 2560, with many input/outputs pins (54 digital pins and 16 analog pins, using 16 MHz with local crystal) to implement large projects that contain sensors, power supply, switches as input while outputs that control the various devices such as lighting, sound …etc. as shown in Figure1. Also any projects that rely on the Arduino can be accomplished by the computer through different programs [15]
3.2 Nodemcu esp8266
There are a lot of devices that are used with the embedded systems and the Internet of Things (IoT) with various features. NodeMCU is a low-cost open-source IoT platform of the microcontrollers with built-in a Wi-Fi 802.11 support b/g/n [16]. As shown in Figure 1. This module comes with a built-in USB connector and a rich assortment of pin-outs. With a micro USB cable, it can use to publish or respond in the database, which uses the MQTT protocol, MQTT is more accurate and requires less time to complete the transmission [17]. From the above, Nodemcu using in many applications, IoT devices, low power battery-operated applications, network projects. Projects requiring multiple I/O interfaces with Wi-Fi and Bluetooth functionalities.

![Arduino Mega 2560, and Nodemcu esp8266.](image)

3.3 Ultrasonic sensor
The HC-SR04 is an ultrasound sensor, operates on a DC 5 volt, that is used to measure distances from 2 cm to 2 meters, as shown in Figure 2, through a Trig pin sends signals at the frequency 40 kHz towards an area or a target, the waves will be reflected and captured by the sensor through an Echo pin [18], the distance is calculated based on the speed of the sound and the time of send and receive.

**Speed of the sound:**

\[
V = 340 \, \text{m/s} \tag{1}
\]

\[
V = 0.034 \, \text{cm/µs} \tag{2}
\]

**Time = Distance / Speed**

\[
T = \frac{S}{V} \tag{3}
\]

\[
S = T \cdot V \tag{4}
\]

For example, if the object is 10 cm away from the sensor as shown in Figure 2, and the speed of the sound is 340 m/s or 0.034 cm/µs the sound wave will need to travel about 294 µ seconds. But what you will get?
Due to the Echo, the pin will be double that number because the sound wave needs to travel forward and bounce backward. So, to get the distance in cm we need to multiply the received travel time value from the echo pin by 0.034 and divide it by 2.

\[ T = \frac{10}{0.034} = 294 \text{ us} \]  \hspace{1cm} (5)

The Distance:

\[ S = T \cdot \frac{0.034}{2} \]  \hspace{1cm} (6)

### 3.4 Infrared sensor

The KY-032 infrared obstacle avoidance sensor is the most widespread in practical applications because of small size and ease of use, its works on a DC 3.3 volt, contains four pins (positive, ground, output, and enable) as shown in Figure 3. the adjustable distance (from 2 cm to 40 cm) is detected by the potentiometer and a pair of transmitter Light-Emitting Diode (LED) and receiver of LED can set the detection distance by rotating the left knob, to the middle for max distance. To control the frequency of emitting IR pulse by the right knob, and to adjust the emitter to the frequency required to work with the receiver [19].

### 3.5 Servo motor

A servo motor is a device that can rotate and move different objects with high accuracy, with different distances and angles that can be set accurately. operates on a DC 0-5 V. Servo motor can be classified of its ability to lift weights at a certain distance, for example, 2 Kg/cm, 7Kg/cm ... etc. [20]. There are many different motors with different torque (high, medium, and small), and low weights as shown in Figure 3. Through these features are used in many Applications cars, planes, robotics, etc.

### 3.6 LCD Screen

The Liquid Crystal Display (LCD) screen display is one of the most popular displays, that can be easily connected with the Arduino. There are several different colors and sizes available, in this paper, we used a Liquid Crystal Display (LCD) 16x2 blue background as shown in Figure 3. It has 16 pins and the first one from left to right is the Ground pin. The second pin is the VCC which we connect the 5 volts pin on the Arduino Board. Next is the Vo pin on which we can attach a potentiometer for controlling the contrast of the display[21].
3.7 RFID Reader
In this paper, we are using the MFRC522 model Radio Frequency Identification (RFID) Reader, which is the device reading the information stored inside the card and tags of the RFID. It is characterized by its small size, low cost, and its ability to read and write, which makes it widely used in embedded systems such as security systems and handheld devices, also, used in conjunction with microcontrollers, especially in opening and closing doors and giving authorized access to some users. The MFRC522 model used 13.56 MHz of RFID card. When the card is rounded to the reader, the information stored in the card will be transmitted to be read, which is a unique serial number as shown in Figure 4 [22,23].

4. Algorithm and operations of the system
In this section algorithm and operations system used are considered:

4.1 System diagram and flow chart
As mentioned above we have used Arduino Mega 2560 board as a programmable microcontroller by the Integrated Development Environment (IDE) Software. In the Figure 5 is a description of the algorithm by using the flow chart of the system in this research.
The miniature model was implemented for the smart parking system. We have used all the same equipment, which is fully described above. It was fully examined, gave extremely and accurate results, and high quality. This miniature model was built to simulate the system in reality. All the details were taken into consideration to stimulate the smart parking system is accurate. It is a suggested model to be applied to reality, specifically in the Faculty of Engineering, University of Diyala.

4.2 The cloud and mobile application
This paper Proposed a unique algorithm that increases the capability of the Smart Parking System Using Ultrasonic Control Sensors and it develops the sensor, and real-time database architecture based on the Internet of Things technology. This system helps the users to find a
spacious parking space in a short period of time. The system will calculate spaces parking in each park. To enhance parking management, an intelligent parking system was developed, this reduced the number of people working in the system, and the parking to maintained and managed more intelligently. The numbers and location of spaces parking will be sent to the data center cloud. Here the database is presented as a cloud that calculates the numbers of empty spaces updated in real-time and is made available to mobile applications at any time. In this system, each parking is an IoT network. This paper implements a system model with Wi-Fi access in an open-source microcontroller platform based on Arduino Mega 2560, and Nodemcu esp8266, and ultrasonic sensors. A smartphone application is built as shown in Figure 6 that acts as a user interface between the data in the cloud as shown in Figure 7, which and the vehicles to check the availability of the numbers of space in the smart parking system.

Figure 6. The Mobile Application.

Figure 7. The Realtime Database.
5. Results and description of the system
As shown in Figure 5, which describes the operation of the system. Authorization access to enter the cars to the parking is used RFID reader. An identification ID card of users was previously created to give the users authorized or deny access. To open the main gate of entry after the authorized access sending a signal to the Servo motor to move forward 75°, which raises the barrier to up. To ensure that the barrier does not come down till the vehicle leaves the gate parking an Infrared Sensor is used. Besides, the same scenario at the exit gate also.

The smart parking system consists of several ultrasonic sensors, which have been set to read the distance we need to give a signal. To read the remaining distance between the car and the barrier behind the car, when the distance is less than 50 cm, it will send a signal to the microcontroller (Arduino Mega 2560), thus reading the ultrasonic sensors to collecting the number of available places as we have shown in table 1. Also, give an alarm (buzzer sound) to Warning the driver not to collide with the fence of the parking. On the other hand, the parking was divided into three positions (the right, the left, and the opposite side). We have used equation (7) to calculate the total of the available spaces. Each side contains several parking spaces, each space contains one ultrasonic sensor. The number of the available place is given, and on which side in the parking. Empty spaces on all sides were calculated by equations 8,9 and 10. The microcontroller is already connected with MCU, which is connected with the internet by Wi-Fi. The data sent to the cloud as a database and stored it. also, the mobile application was used. The mobile application gets the data (numbers of spaces and the locations) from the cloud; thus, it is displayed on the user's mobile screen.

\[ Space_T = S_{right} + S_{left} + S_{opposite} \]  \hfill (7)
\[ S_{right} = \sum_{i} Ur > 50 \text{ cm} \]  \hfill (8)
\[ S_{left} = \sum_{i} Ul > 50 \text{ cm} \]  \hfill (9)
\[ S_{opposite} = \sum_{i} Uo > 50 \text{ cm} \]  \hfill (10)

Table 1: Sensors readings and results

| \( U_{R1} \) | \( U_{R2} \) | \( U_{L1} \) | \( U_{L2} \) | \( U_{O1} \) | \( U_{O2} \) | \( S_R \) | \( S_L \) | \( S_O \) | \( S_T \) |
|---|---|---|---|---|---|---|---|---|---|
| < 50 cm | < 50 cm | < 50 cm | < 50 cm | < 50 cm | < 50 cm | 2 | 2 | 2 | 6 |
| > 50 cm | < 50 cm | > 50 cm | < 50 cm | > 50 cm | < 50 cm | 1 | 1 | 1 | 3 |
| < 50 cm | > 50 cm | < 50 cm | > 50 cm | < 50 cm | > 50 cm | 1 | 1 | 1 | 3 |
| > 50 cm | > 50 cm | > 50 cm | > 50 cm | > 50 cm | > 50 cm | 0 | 0 | 0 | 0 |

Table 1 shows the results we got by taking some readings from the ultrasonic sensors (two readings from each side of the parking).

where:
\( U_{R1}, U_{R2} \): The first and second ultrasonic sensors on the right side of the parking.
\( U_{L1}, U_{L2} \): The first and second ultrasonic sensors on the left side of the parking.
\( U_{O1}, U_{O2} \): The first and second ultrasonic sensors on the opposite side of the parking.
Sa, Sl, So, ST: Available spaces parking on the right side, available spaces parking on the left side, the total available spaces parking respectively.

As noted in table 1, we have adjusted the sensors to measure the remaining distance between the car and the barrier (UR, UL, U0 U1). When it is less than 50 cm, an indication of a car in the place, thus the number of places (SR, SL, SO, ST) is decreasing. This was calculated according to equations (7,8,9 and 10).

6. Conclusion
This paper, proposed to design and implementation of smart parking based on ultrasonic sensors, infrared sensor, RFID Reader, Nodemcu esp8266, and servo motor all these equipment are connected with Arduino and mobile application to calculate the number of available spaces and locate the space in the parking to help the driver and rid him of accidents and chaos caused by not knowing the empty places in the vehicle parking, It facilitates searching for a more reliable vehicle parking space because it contains authorized to access and mobile application… The new system metrics consider the distance and the total number of free spaces in each car park and thus minimize the waiting time and improve the probability of successful parking. Finally, the system relatively is cheap, is the current trend of today’s technologies. Any institution or university can easily manufacture and use it. moreover, it’s a unique design that is very easy to implement by everyone.

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