1. Background

Finding a parking spot may seem like a superficial problem or an individual problem, but it is, in fact, a problem that causes significant issues in the day to day life of people. In metropolitan areas worldwide, having a parking area is increasingly important, and a substantial amount of land and buildings are set aside to accommodate the growing demand for parking spaces. For instance, in Australia, parking areas hold great importance especially in Brisbane, Sydney, and Melbourne where they have a vast number of parking spaces ranging from 25,633 to 41,687 [8]. Furthermore, estimates show that around 30,000 square kilometers of land in Europe and 27,000 square kilometers in the US are devoted to parking spaces [9].

Moreover, parking can be very time consuming and costly. Hence, it comes as no surprise that “The U.S. economy bears the brunt of parking pain as 40% of drivers say they have avoided driving to shops due to parking challenges.” [10]. According to a study from car service company Inrix, Americans spend an average of 17 hours per year searching for a vacant parking spot, and this leads to a loss of $345 per driver in wasted time and fuel. Similarly, drivers in the UK spend an average of 44 hours a year looking for empty parking, with an estimated total loss of £733.

Contrary to the popular belief that generous parking allocations benefit users, the opposite can happen when there is an exaggeration in parking allocations. A big parking lot prolongs transportation time and is a waste of useable land. These effects -along with recent land-use, socioeconomic and technological trends- are prompting towns to begin asking some critical questions about how to solve the parking problem smartly and cost-effectively. For this reason, there have been many attempts to provide smart parking systems as a solution, with each having its different approach as shown in the Related Work section.

2. Related Work

Several studies conducted and presented in previous literature related to our project have helped us in the development and implementation of our design.

A Secure Parking Reservation System Using GSM Technology

[11] have used GSM technology to propose a secure and smart reservation system for parking areas. The system consists of two major modules which are security reservation module and parking lot monitoring.

Secure Reservation Module

The main idea is that the user has to send an SMS message using GSM (Global System for Mobile communications) to a Visual Basic (VB) application in a laptop/PC. The VB then processes the requested data and checks the available spot. They use open APIs in VB to handle SMS messages. If the requested parking lot is available, the user will receive a confirmed message that has the location for the spot and password. Otherwise, it will receive a reject message.

Parking Lot Monitoring Module

The primary aim of this module is to show the status of the parking spots using Parking Layout Animation program through Visual Basic application in a laptop/PC. Their program displays the status of each parking spot through colors. Green for empty, yellow for reserved, and red for occupied. Initially, the state of all parking spots is empty. The status will change to reserved if the user successfully reserves a parking spot. When the user arrives at the entrance gate, he enters the password and then the controller will verify this password. If the password is valid, the gate will open, and the Parking Layout module will update the spot status to occupied.

By using this approach, the user will be charged by the telecommunication company to send SMS messages. Also, GSM is prone to be easily congested in crowded areas [12]. In their approach, all information is stored locally on one computer which is inefficient as the computer memory will eventually be too full to save any more information from the system. Also, if the computer is somehow damaged, all the data will be lost.

Intelligent Parking Space Detection System Based on Image Processing

[13] used an image processing technique to detect if the parking lot is empty or not. The proposed solution is carried out in 5 steps as follows:

1- System Initialization:

In the beginning, a rounded brown image is drawn at each parking manually to determine their positions.

2- Image Acquisition:

The camera captures an RGB image for the car park scene and sends it to the processing unit that runs in MATLAB.

3- Image Segmentation:

MATLAB converts the RGB Image to a grey scale image. Then thresholding technique on the grey scale image is applied to create a binary image. This technique helps in separating the objects from the background.

4- Image Enhancement:

The morphology functions such as dilation, erosion, opening, and closing are used to remove noise from the binary image as well as to trace the exterior boundaries of the object.

5- Image Detection Module:

The system detects if the parking lot is empty or not by identifying the rounded brown image at every spot.

This approach may not function well in extreme weather conditions as the camera might be damaged. Also, placing the camera in a suitable location such that all parking areas are visible, and there are no objects that might obstruct the camera's vision is essential for the camera to work as planned.

Monitoring Parking Space Availability via Zigbee Technology

In [14], the system’s primary function is to allow its users to view the available parking spots through a screen at the gates of a parking area using Zigbee wireless technology for communication and digital infrared sensors for vehicle detection.

The system consists of two main modules:

Parking Lot Vacancy Monitoring Module

The module comprises of digital infrared sensors, Zigbee module, PIC microcontroller 18F4550, and an LCD. This module is used to detect the available parking spots. A digital infrared sensor is implemented on top of each parking spot to detect the existence of a vehicle such that each sensor is used to monitor one parking spot. Infrared sensors work with the reflected light wave and consist of an IR transmitter and an IR receiver. The IR transmitter emits infrared light, which gets reflected when it meets a reflecting surface (e.g., white color). The IR receiver then detects the reflected light and calculates the distance between the sensor and the object. The infrared sensor interfaces with a PIC microcontroller, which also interfaces with a Zigbee module for wireless transmission. When the sensor senses a vehicle in the parking spot, it informs the microcontroller, and then the microcontroller notifies the master module through the Zigbee module.

Master Module

The master module consists of a GUI display shown through a PC or a laptop, and a Zigbee module. The GUI display, shown in Figure 2-7, allows the user to see precisely which parking spot is available. Whenever the Zigbee module receives data about a particular parking spot from the Parking Lot Vacancy Monitoring module, it informs the PC/laptop that it is interfaced with to update the status of a parking spot.

However, this system has several disadvantages. The infrared sensor is hugely dependent on light as brighter surfaces are more accessible for detection than darker surfaces. Hence, changing light conditions could give wrong outputs. Also, the system does not have a mobile application for a remote user interface and restrict its users to a GUI interface at the gates of the parking lot.

Figure 2-8 shows the hardware architecture of the system.

Smart Parking System (SPS) Architecture Using Ultrasonic Detector

[15] is a smart parking system for multilevel parking lots which uses ultrasonic sensors to detect the occupancy of a parking space and shows it to the user at the parking area using display boards. The display boards display the number of available parking spots, and they are implemented indoors, at the entrance to each level and the end of each aisle of the parking lot, and outdoors, at the entry and exit of the parking lot. Furthermore, an ultrasonic sensor is installed on the ceiling of a parking spot and is used to detect cars on that spot only. LEDs with different colors accompany each ultrasonic sensor to inform the user of the parking spot status (reserved, occupied, vacant or handicapped). Moreover, The system includes a monitoring software and line detection system to detect improper parking. The line detection system is implemented by adding two additional ultrasonic sensors horizontally on the right and left of each parking spot such that they face the parking spot lines. Whenever a car goes over the detection line, an alarm will go off until the vehicle has moved out of the line.

Figure 2-9 shows the overall hardware architecture of the system. The system consists of ultrasonic sensors, LED indicators, indoor display boards, outdoor display boards, zone control units (ZCU), a central control unit (CCU), network switch, telephone cable, and management software. When the ultrasonic sensor detects a change in the status of a parking area, it transmits the status to the zone control unit (ZCU) through a telephone cable. The ZCU then forwards the information to the central control unit (CCU) with Cat5 cables and sends commands to the indoor display boards and the LEDs on the parking sports to change status accordingly. Both the indoor display boards and the LEDs connect to the ZCU through RS-485 ports. The ZCU connects to the central control unit (CCU) through network switch and LAN connections. The CCU upon receiving new information from any of the ZCUs processes the data with the whole parking lot data, then transmits commands to the outdoor display boards to update the parking area information.

The system manages the multilevel parking area nicely. However, the system contains a lot of hardware components and connects its components through cables. Any extension to the system would require more cables and more complications on the system.

Intelligent Parking System

In [16], the system uses image processing techniques which capture and process circles or rounded images drawn from the parking lot and shown in an android application. This rounded image indicates empty parking spaces to users.

A camera is used with a sensor to take photos to show the occupancy of car parks. The application displays whether a parking space is available or not. If the camera detects the vacancy of a parking area, a green circle appears to the user. If there is a car in a spot, it becomes unavailable, and no green circle is shown at that spot in the application.

The system contains three modules: a Monitoring module, Control module, and a Displaying unit. The monitoring module has ultrasonic sensors which identify the free parking spaces and transmits information to the control unit which processes/sends data to the administrative system. Besides that, there is a centralized system that supervises the received parking information from the controller. It then sends the data to the user’s phone.

Below (Figure 2-10) illustrate the working process of the system.

Table 2-1 compares the existing solutions to ParQU. All the related works implement one of the following services: Checking Availability, Reservations, Payment except [16]. [16] gives all the above functions that we aim to provide in our system. However, [16] only implements an Android application while we will provide a website in addition to that. Furthermore, the above approaches use ultrasonic, infrared and camera for car detection only. Our method uses an ultrasonic sensor for car detection and RFID (Radio Frequency Identification) for car identification and detection.