Smart Parking Management Using IoT and ESP32: A Real-Time Monitoring System

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Abstract. As the number of vehicles on the roads continues to rise, finding an available parking space in busy areas has become increasingly difficult. A smart parking system powered by the Internet of Things (IoT) provides real-time updates on parking availability, making the process faster and more convenient. This system simplifies the car parking process from entering the vehicle to making payment and exiting. The proposed system uses NodeMCU, a bunch of five IR sensors and two servo motors to detect vehicles and find empty parking slot. Two IR sensors for car sensing for entry and exit gate and three IR sensors for the status of parking slots available. The gates are driven by servo motors that react to sensor readings and opens and closes the gates. The data is posted on the Adafruit IO, for worldwide monitoring. There are an overall of five IR sensors and two servo motors connected to the NodeMCU. The NodeMCU is in charge of running this process and sending parking availability data as well as the time to Adafruit IO.

Keywords: Internet of Things (IoT), Parking System, NodeMCU, Adafruit IO.

1 Introduction

Parking in modern cities is a major problem. The problem is that there are too many cars on the roads and not enough places to park them. The research team identified the need for intelligent parking management. To serve their purpose, they use IR sensors to figure out whether parking slots are empty or occupied, along with a DC motor to mimic the gate moving servos. The system connects to the Internet via a Wi-Fi modem, and a microcontroller manages the system. They offer a website that allows the user to make GUIs for connecting to the net and managing IoT. The occupancy of the parking spots is detected by infrared (IR) sensors in the system. The attached counting of available and occupied parking slots and its synchronisation with cloud server with the help of the cloud-based server can facilitate the online parking lots availability monitoring [1]. Users conveniently obtain the real-time parking place information from anywhere online, so as to have no obstacles for an easy parking. Thus, the system solves the parking problem in urban area efficiently and offers a simple Internet-of-Thing (IoT) cloud-based parking management service for parking users. The birth of the Internet of Things (IoT) can be dated from the adoption of communicative devices with unique identities. The gizmos are remotely traceable, controllable or observable from Net-connected computers. The IoT extends the use of the Internet to communication and internetworking between devices and physical objects, which are often called "things". Internet and things are the two big words in IoT. The Internet is a vast system that interconnects servers, computers, tablets and other devices organised by international standards protocols in order to connect therebetween. The Internet

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is a network that allows the sending, receiving, and sharing of information. The vision is towards the making of various objects such as wearables, watches, alarm clocks, home appliances, and the environment θ smart. This is accomplished by means of tiny implanted objects that can sense, compute, and communicate. These devices can connect remote objects or people. Considering its scalable nature and robustness, application developers can be able to design and host their apps on cloud computing. The cloud is a natural partner for IoT as it's a place to hold data from far flung sensors. These factors have led to consolidation of these technologies and birth of a new technology called CoT (Cloud of Things). In the CoT perspective nodes among CoTs can be accessed, monitored and controlled as remote through cloud technology. With such great scalability of the cloud, nodes in the IoT system can be increased. The IoT has control, monitoring a physical object mixed controller, sensor and actuator; they are connected to mankind and can be or added or removed by (n) and (n) representing the integer part of the positive real number "0" [2]. In [3] an IoT-based intelligent parking system for a vast parking zone is proposed. Intended to ease traffic flow, it provides real-time parking slot information via a mobile app. The product uses IoT technology to guide individuals to the nearest available parking spot.

Reference [4] presents a smart parking energy management scheme for the multi-floor business parking lot. The parking system is based on IoT technology and uses Honeywell's sensors to ensure organized parking. Brilliant items signal unoccupied spaces, and show passers-by how to get there. Occupied areas are stored on a cloud server, and light is dimmed to lower levels to save energy. The system makes parking more efficient and time-saving for users.

The Internet of Things (IoT) [5] is an emergent field, with many advantages and less human effort. The increasing population leads to the increasing number of vehicles, which further increases transportation dependence and a tougher parking situation in the city precincts. Conventional mechanical indoor parking systems are inconvenient, spread traffic jam and accident. Intelligent outdoor parking facilities with weighbridge load sensors can be efficient, flexible and convenient, and safe public parking systems.

A smart parking system based on IoT in [6] addresses most of the challenges encountered on traditional parking lot. The mechanism makes use of a smartphone application in connection with Infrared sensors, radio-frequency identification (RFID) and Arduino technology to know exactly where parking is available, and know too how to ensure that drivers can avoid unnecessary driving. Drivers can easily find nearby parking lots, book them and pay through an in-app wallet. The method improves efficiency, reliability and convenience, and reduces resources consumption and pollution.

Smart cities are increasingly adopting the Internet of Things (IoT) to enhance the functioning of urban infrastructure and productivity [7]. But in these metropolises, scarce parking spots and snarled traffic mean wasting time and getting behind in paying In this paper, a new parking e-ticketing system has been proposed where vehicle entry and exit are controlled, parking fees are deducted and number of vehicle parked are counted. Should the account have the required funds the owner receives a message on their mobile phone and the system will open the parking gates – reducing the time spent looking for an empty space.

2 Problem Statement

Difficulty in locating available spaces in a multilevel parking garage is highly problematic, especially during weekends or public holidays. For around two-thirds of visitors, finding parking spaces during weekends or public holidays can take more than 10 minutes. During peak hours, stadiums and retail centers are heavily crowded, and customers may have significant difficulties finding available spaces at these locations. Insufficient car parking spots lead to congestion and frustration among drivers [8]. The objective of the study is to develop and execute an intelligent system that will be utilized in intelligent parking garages to facilitate the identification of available parking spots [9, 10].

3 Proposed Design

The project is essentially divided into two primary components: hardware architecture and software details. The circuit design was implemented in the hardware architecture, and a prototype of the project was developed. Throughout the software development process, the entire prototype was controlled.

3.1 Hardware

There are a wide variety of Arduino boards available, each possessing unique characteristics and capabilities. The project utilizes several highly sought-after boards, including:

3.1.1 ESP8266 NodeMCU

NodeMCU (shown in Fig 1) is a cost-effective platform that utilizes the ESP8266 Wi-Fi enabled chip and is available as an open-source solution. The device utilizes an on-module flash-based SPIFFS file system, which is built on top of the Espressif Non-OS SDK. NodeMCU is a microcontroller board that resembles Arduino and has pins that can be programmed, as well as built-in Wi-Fi and a micro-USB connection. The device can be programmed using several software platforms and is equipped with a built-in Wi-Fi module, which helps to minimize power usage and save space. NodeMCU can be readily connected to any suitable USB port [9].

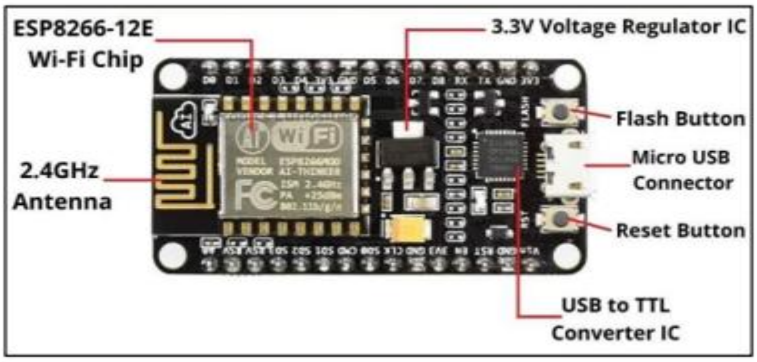

Fig. 1. Layout of NodeMCU.

3.1.2 IR Sensor

An infrared sensor, often known as an IR sensor, is an optoelectronic component that detects and responds to radiation in the infrared wavelength range of 780 nm to 50 µm. In contemporary applications, infrared sensors have become extensively employed in motion detectors. These detectors are used in building services to activate lighting systems and in alarm systems to identify intruders. The sensor components detect variations in heat radiation, specifically infrared radiation, brought about by people's movement in both time and space within a given range of angles. Infrared sensors of this kind merely need to fulfil modest specifications and are inexpensive. The Fig 2 shows IR Sensor.

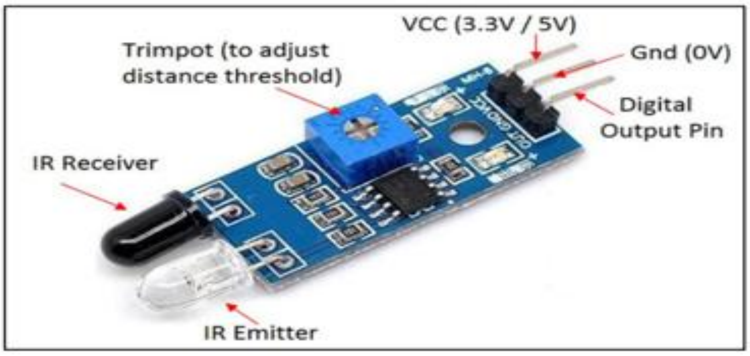

Fig. 2. IR Sensor.

3.1.3 16x2 LCD Display + I2C Module

The 16x2 LCD display is employed for providing parking slot availability status in real-time. Control is done through I2C (Inter-Integrated Circuit) which decreases the number of pins required for connection. The LCD is two lines of 16 characters per line, perfect for displaying If there is available parking or if the lot is full. I use an I2C module which makes wiring easy and has the advantage of being able to run multiple devices off the same bus. The Fig 3 shows 16x2 LCD Display + I2C Module.

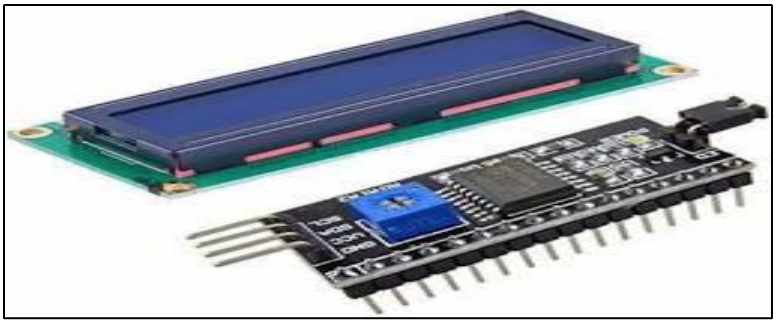

Fig. 3. 16x2 LCD Display + I2C Module.

3.1.4 Zero PCB

All electronic parts are secured in and organized by Zero PCB (Printed Circuit Board). Other than breadboard, which is for prototyping only, zero PCB would mean a more permanent, compact circuit. It reduces the wear and tear of tool during using process, makes the circuit to be more stable and can prolong the life. The Fig 4 shows Zero PCB.

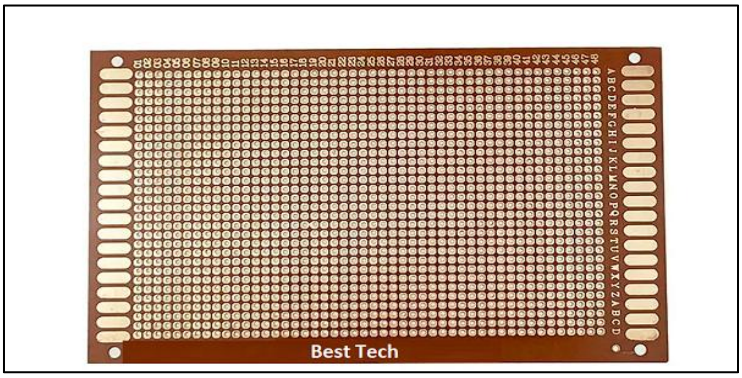

Fig. 4. Zero PCB.

3.1.5 18650 Lithium-ion Battery

The rechargeable 18650 lithium-ion battery constitutes the main power supply for the system, and can guarantee continuous working even when confronted with no external power input. These cells have high energy density, long cycle life, and stable voltage output. The power management of the ESP32 means that it has reasonable battery life potential and can be used for solar-powered projects, for example, outdoor parking lot installations where there may not be a convenient power supply. The Fig 5 shows Lithium-ion Battery.

Fig. 5. Lithium-ion Battery.

3.2 Software

3.2.1 Arduino IDE

The Arduino IDE is a freely available piece of software used for authoring and compiling code for Arduino modules. It may be used on MAC, Windows, and Linux operating systems. The software operates on the Java Platform and encompasses features for debugging, modifying, and compiling code. The Arduino modules consist of the Arduino Uno, Arduino Mega, Arduino Leonardo, and Arduino Micro. The IDE environment comprises a text editor and a compiler that provide support for the C and C++ programming languages. It enables novices to acquire and enhance their proficiency in Arduino.

3.2.2 Adafruit IO

Adafruit IO is an open data platform that enables the aggregation, visualisation, and analysis of live data on the cloud. It allows users to upload, display, and monitor data over the internet, enabling IoT projects. Adafruit IO is free for testing and experimenting and has been previously used with the Raspberry Pi. To use Adafruit IO, create an account on the Adafruit IO website and log in to obtain your username and AIO key. Copy these keys and usernames for future use in code [11, 12]

4 Design and Implementation

The scheme illustrates the flow of inputs and outputs in the project's' work. For instance, when a car intends to park, the infrared (IR) sensor transmits a signal to the nodemcu, which in turn provides a signal to the servo motor. Additionally, the IR sensor for the output gate becomes operational. Additional infrared sensors are used to determine if a vehicle is positioned in a secure area. The outcomes are then showcased on Adafruit IO and a mobile application [9,11,12].

The following schematic represents the connection of the hardware components of the project, which is connection for programming, as the scheme fig 6 shows the connection of each sensor and other piece with its respective ports.

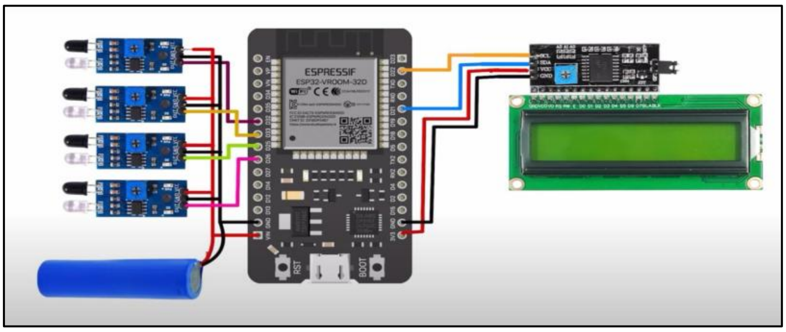

Fig. 6. Schematic diagram of the proposed system.

The Fig 7 diagram illustrates the operational process of the programming code, wherein the initial IR sensors ascertain the presence of any vehicle at the input gate and determine whether the parking area is at maximum capacity or not. If the park reaches its maximum capacity, the entrance gate is closed, and the park is marked as full in the application.

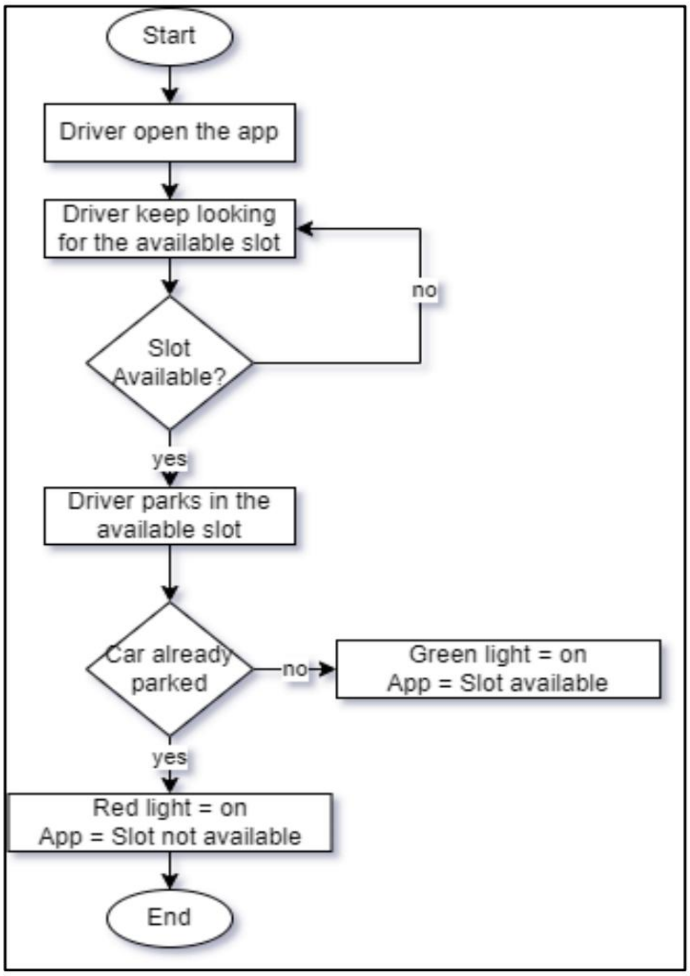

Fig. 7. Flowchart for the proposed algorithm.

5 Results

Based on the design schematic, the hardware level of the system has been introduced in this section. The fig 8 shows Final Design.

Fig. 8. Final Design.

At the start of the project, the IoT will be depicted visually, as shown in. According to the parking count, it can be deduced that there are zero cars parked at the location. presents a graphic depiction of a parking lot that is not currently being used.

When a vehicle enters the park, the sensor will be triggered, causing the car parked counter to increase by 1, as shown in. In addition, a servo motor will operate the entry gate. Afterwards, the car moves towards an empty parking spot, such as the first available space. The infrared sensor enables the transfer of information on the duration of parking and the time of departure of a vehicle from a specific parking spot to the IoT platform, as shown.

6 Discussion and Future Works

The concept of incorporating wavelet [13] and multiwavelet [14, 15, 16and 17] transforms into the system described here is an interesting proposition. Here's how these transforms could potentially improve parking availability prediction. Feature Extraction from Sensor Data: using Wavelet and multiwavelet transforms [18] can be used to analyze the data collected from IoT sensors in parking spaces. This data might include ultrasonic sensors where signal variations can reveal presence/absence of a vehicle and potentially information about vehicle size. Magnetic sensors usually change in magnetic field can indicate vehicle presence. Cameras (if used) will include image analysis using wavelets could extract features related to occupancy or parking space condition (e.g., blocked by cones).

They can result also in capturing Temporal Variations as Wavelet transforms are good when dealing with signals in time [19]. This enables taking snap shots how sensor readings vary, in turn displaying patterns that correlate to parking throughout the day. And, thus such idea will enhance feature representation by dividing sensor data into various frequency bands. Note that wavelets have the ability to extract more useful features than raw sensor readings. The new features can then serve as input for the ensemble model. Multiwavelets procure more freedom than single wavelets. With carefully selecting wavelet basis, it could have better adaptive character to the particular data of the sensor. Applying these transforms to the Ensemble Model results in the following benefits:

1. Feature Engineering: The wavelet and multiwavelet transform features can also be concatenated with [other] information's, for instance, day, weather, in the case of the electricity data: events. This enhanced feature playlist can serve as input to the ensemble model for both training and prediction.

2. Possibility of Increased Accuracy: Several features may be included to capture richer and more informative aspects of the sensor data and parking availability dynamics which will provide a better prediction power for the model.

But there are a few challenges that will have to be overcome:

1. More complex: Computing the wavelet and multiwavelet transformations introduce another layer of complexity into the system, needing domain/redshift expertise and possibly making it more computationally expensive to run.

2. Data Volume: The wavelet transform may lead to a higher volume of features than raw sensor readings. This may affect the amount of storage and potentially training time for the model's ensemble.

3. Hyperparameter Tuning: the choice of wavelet bases and parameters for the transforms needs to be tuned to achieve the best possible performance. Generally speaking, the integration of wavelets and multiwavelets offers great promise in enhancing the prediction of parking availability by representing machine learned features from sensor data in a more informative space. But increased complexity, the possibility of the larger number of data, or the concentration of the input data point and the model parameter, and the requirement of careful hyperparameter tuning have to be balanced against the potential advantages. Better results can also be obtained by employing some of the hybrid transforms [20] such as Walid let transforms, FAW and COW transforms. Recent studies using these hybrid transforms are shown in a number of publications [20]. Through combining Swin transformer with transformation strategies, we save time on choosing, combining, generating or transforming more features to effectively address the problems of performance and computation time. One reason to study this is of course that we want such systems to build as opposed to one-task-and-no-other-problem tools.

7 Conclusions

Car parking remains a persistent challenge in urban and commercial areas, often contributing to congestion, wasted time, and driver frustration. This study proposed and implemented an IoT-based smart parking system that integrates an Arduino microcontroller, Wi-Fi module, and NodeMCU to enable real-time monitoring of parking slot availability. By leveraging cloud connectivity, the system improves the efficiency of parking management, reduces search time, and enhances user convenience.

The contribution of this work lies in demonstrating a cost-effective and scalable framework for smart parking that combines sensor-based detection with cloud integration. Unlike conventional parking systems, the proposed design enables continuous monitoring and supports remote access to availability information, offering practical benefits for both users and administrators.

Looking ahead, the system can be further enhanced by incorporating RFID-based vehicle access, camera-based identification for improved security, and integrated online booking and payment systems. Such advancements would create a seamless, user-friendly parking experience and contribute to the broader vision of intelligent transportation systems within smart cities.

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