

An IoT-Based Real-Time Intelligent Parking Management and Direction Guidance System

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Abstract—Parking Lot Problems are very usual these days especially at those universities when vehicles are entering at peak hours that results in congestion and scarce utilization of parking space. Smart Car Parking System using Arduino Uno along with IR Sensors, servo motor based Barrier, LCD display with ESP8266 for IOT based monitoring has been discussed in this paper. The system is developed with the objective of reducing unnecessary vehicle movement inside parking areas and improving overall traffic flow. Multiple IR sensors are placed at individual parking slots to detect vehicle presence and determine occupancy status in real time. An entry sensor is used to identify incoming vehicles, and based on slot availability, the system either allows or restricts entry using a servo motor acting as a boom barrier. The LCD display provides continuous updates of slot status and dynamically switches to guidance mode when a vehicle arrives, directing the driver to the nearest available slot. To enhance system functionality, the ESP8266 module is integrated with a mobile-based monitoring platform, enabling real-time remote monitoring of available slots, manual gate control, parking full notifications, and basic entry logging through a mobile application. This reduces dependency on physical presence and improves system accessibility. The proposed system offers a low-cost, scalable, and efficient solution for small to medium-sized parking areas. It combines automation, real-time sensing, and IoT capabilities to address common parking issues such as congestion, unnecessary entry, and lack of information. The implementation demonstrates how embedded systems can be effectively used to improve parking management in practical environments.

Index Terms—Smart Parking System, Arduino Uno, ESP8266, IR Sensors, IoT, Real-Time Monitoring, Parking Automation, Embedded Systems, Remote Control

I. INTRODUCTION

Parking management has emerged as a significant concern in today's world. The density of vehicles has been high in commercial areas like educational institutions, shopping complexes, and office buildings. Especially during peak hours drivers wander around to find an empty slot. This causes wastage of time and unnecessary movement of vehicles resulting in traffic congestion. As people enter parking lots without any knowledge of the occupancy state vehicles get overcrowded. So there is a demand for a system which intelligently solve this problem with real time information about availability and access control for the vehicles.

The current parking system available mostly includes manually operated systems or no embedded systems which are updated in real time. These systems do not sense the parking

scenarios dynamically and often leave the users confused. With recent development in the field of embedded systems and IoT of smart parking systems can ease the parking availability and management [1], [6]. Implemented with sensors, microcontrollers and communication modules these systems sense the parking spaces.

Few approaches have mentioned parking solutions with Wireless Sensor Network, Cloud Platforms and Mobile Applications. [9], [13]. However these systems only scale to large parking environments. College Campuses for example lack a low-cost scalable system. Microcontrollers like Arduino with communication modules such as ESP8266 allow us to create these systems.

The proposed project is Smart Car Parking System Implemented using Arduino Uno board with IR sensor, servo motor, a LCD display, ESP8266 module. The IR sensor will check whether each slot is occupied or not and displays the number of empty slots that are available at any time. If a car approaches the entry point, then it checks the availability of empty slots. If any slots are available, then entry will be allowed by opening the gate and if no slots are available then the gate will remain closed so that no cars can enter into the parking.

Beyond simple automation, the system features realtime monitoring and remote access through Blynk. Occupancy is shown through available slots and alerts when parking is full. Manual gate control can be enabled for override as needed. Overall this adds robustness to the system as well as convenience for users by pairing local automation with IoT monitoring.

The goal of this project is to design and develop a practical inexpensive, cost-effective and easy to implement parking management system that solves the existing problems faced in the real world scenario like Avoid Unnecessary Entry, Avoid Traffic Jam inside the Parking Area, No real time info etc. The system designed shows how an Embedded system can be used along with IoT to implement practical solutions for Smart Parking.

II. LITERATURE SURVEY

Parking systems have been one of the most explored domains in recent years owing to the escalation in vehicular

population and vehicular space management necessities. Embedded systems, wireless networks and internet of things (IoT) enabled approaches have been presented towards mitigating parking issues. The solutions work primarily on real-time parking space monitoring, automation and guidance.

There have been many methods which use IoT-based architectures. Sensors that help detect the presence of vehicles can send this information to an administrator in real time. Sharma and Gupta [1] introduced an IoT-based Parking system that uses Arduino technology that communicate with the Cloud servers. Users can easily view the availability of parking spaces from anywhere using this application. Lee et al. [6] discuss the development of a wireless sensor based parking system that uses IoT communication standards to relay real-time parking availability data to users. Many of these systems allow for ease of access however they require consistent internet/cloud connection.

Systems that fall under another category make use of wireless-sensor networks (WSN) to solve problems with large scale parking systems. Nguyen et al. [13] had discussed about distributed-sensor nodes used to detect the presence or absence of cars in parking slots that helped data be sent with less traffic. Such systems work well when deployed on a large scale (metropolitan areas) but prove to be expensive and difficult to setup on a smaller scale (College Campuses).

Works have also been done by various authors concentrating on Embedded System based cost friendly solutions which are easier to setup. Karthik and Kumar [5] had implemented a parking system which automates the entry/exit of vehicles using Arduino with simple sensors. Verma et al. [10] had also used IR sensors which helped in vehicle detection. IR Sensors are one of the simplest and cheap sensors. Such solutions work well locally but lack the ability to be accessed remotely.

As Mobile Applications were evolving various developers have started integrating their systems with blynk. Mehta and Jain [7] introduced smart parking system where user can check availability of parking space and operate parking through mobile application. This is user friendly and flexible approach as there is no requirement of web designing.

Hybrid solutions with local automation and IoT based remote monitoring were also presented recently. A low-cost smart parking solution with embedded hardware platform and real-time communication was proposed by Reddy et al [8]. An overview of the current parking technologies with future scopes was provided by Chen and Zhao [15]. Scalability, real time updates and ease of use were some important aspects they discussed.

Mobile apps can be easily integrated as well. Applications can work with Blynk or any other platforms. Mehta and Jain [7] describe an application based parking monitoring and control system. Using a smartphone application can allow for ease of use for users to see parking availability and operation. This would allow users to easily interact with the system without the need of specialized website front ends. Even Hybrid systems have only very recently been looked into. Reddy et al. [8] Implemented a hybrid system with low cost

smart parking control and communication using embedded hardware with IoT. Connectivity Reddy et al. Systems like this can allow for localized automation of these smart systems while still having the ability to access and communicate with these systems through the web.Chen and Zhao . [15] With these properly built website front ends these systems can be scalable, allow real time updates, and be user friendly.

While some existing solutions have many good features, they either try to apply to large systems or require hardware that could cost a lot of money. This left a gap for an easy-to-use and low-cost efficient parking system that could work well in small scales with features such as real-time tracking, access control, and user guidance.

The system we have presented in this paper covers these flaws by implementing Arduino for local controller and ESP8266 as IoT capability. It strikes a good compromise between price, performance, and ease of use and could work very well in real life such as college parking lots.

III. PROPOSED SYSTEM

The system will give low-cost and effortless parking facility to the users. It will provide live monitoring of slots using embedded system and wireless communication technologies. It controls the entry of vehicles into the parking space and guides users to avail the services easily. Hardware components such as sensors, microcontroller and communication module are used.

A. System Overview

The project uses IR sensors at every parking slot , Entry IR sensor ,Arduino Uno,servo motor and LCD display. an Wi-Fi module is kept which helps in viewing status of the parking lot remotely. Steps in which it operates are: Detects parking occupancy.Compute parking vacancy.Manages Entry.Exit.gate Displays on LCD

B. System Architecture

Fig. 1 presents the architecture of the proposed system. Sensors send data constantly to the microcontroller. The microcontroller processes the information and gives commands to the gate and display. The communication module sends data for remote monitoring.

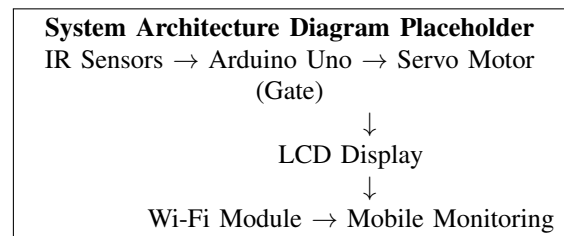


Fig. 1. System Architecture of Smart Parking System

C. Working Principle

The working of the system can be explained in the following steps:

- IR sensors sense whether the parking slot is occupied or not.
- The microcontroller unit keeps on reading the sensor status and updates the slots availability status.
- When a car approaches the entry point, the entry infrared sensor gets triggered.
- The system will sense the number of free slots available.
- If there are free slots then entry gate will open through the servo motor.
- The gate will not open if the parking is full and this avoids congestion.
- The LCD display will show which slots are free or occupied along with driving instructions.
- Parking data is also transmitted for remote monitoring and control.

D. Hardware Components

The main hardware components used in the system are listed in Table I.

TABLE I
HARDWARE COMPONENTS USED

S.No	Component	Function
1	Arduino Uno	Main controller for processing data
2	IR Sensors	Detect vehicle presence in slots
3	Servo Motor	Controls entry gate
4	LCD Display	Displays slot information
5	Wi-Fi Module (ESP8266)	Enables remote monitoring
6	LEDs (optional)	Indicate slot availability

E. Key Features of the Proposed System

The important features of the system are:

- Monitor availability of parking slots.
- Automate gate control as per parking slot status.
- Avoid Unnecessary entry of vehicles.
- Guidance to user using LCD Display Messages.
- Monitor remotely with manual override option.
- Cost Effective easy to build system.

F. Advantages of the Proposed System

The proposed system offers several advantages:

- Reduces traffic jam in the parking lots.
- Helps to use space efficiently.
- Lowers searching time for slots.
- Offers scalability for small and medium parking areas.
- Convenience for users.

G. System Modules

The proposed system is divided into the following functional modules:

- **Sensing Module:** IR sensors detects the presence of vehicles in each slot as well as at entry point

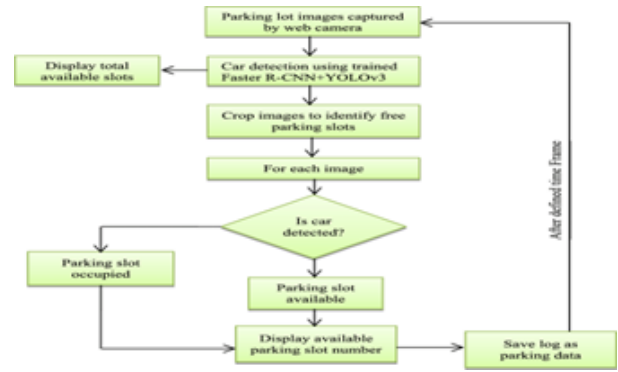


Fig. 2. Flow Diagram of the Parking System

- **Processing Module:** Arduino Uno microcontroller process the signals given by sensors and also checks whether slot is available or not.
- **Control Module:** servo motor will be used to open and close the gate according to availability.
- **Display Module:** LCD is used to display the live status of parking system as well as display guiding messages.
- **Communication Module:** Wi-Fi module is used to monitor the system remotely.

IV. HARDWARE ARCHITECTURE

The hardware architecture of the proposed smart parking system defines the physical components and their interconnections required for implementation. The design focuses on simplicity, low cost, and reliable performance while ensuring efficient real-time operation. The system integrates sensing, processing, control, display, and communication units to achieve automated parking management.

A. Component Description

The major hardware components used in the system and their functions are described below:

- **Arduino Uno:** It is the brain of our system. It reads input signals from all sensors, processes it, and calculates which slots are available for parking. Once done, it controls the servo motor according to the calculations and displays the result on LCD. It also sends information wirelessly via Wi-Fi module. Arduino is preferred as it's simple, available easily and is easy to program for embedded applications.
- **IR Sensors:** Parking sensors send IR signals and capture the reflected data by the sensor. If there is no vehicle IR sensor detects reflection by the objects around it. If a vehicle is present IR sensor output will change accordingly which means that vehicle is there at parking slot or entry IR sensor. Sensors are cost-effective and easy to install also has short range which can easily be implemented for parking.
- **Servo Motor:** The servo motor is utilized to open/close the entry gate. Control signal from the Arduino and rotate to determined angle that indicates position of the gate

opening. The servo motor was used to rotate the gate to a certain angle. This allows precise control when moving the gate allowing it to operate reliably. Prevent vehicle from entering when parking lot is full.

- **LCD Display** : LCD Interface gives information about the system to user. The LCD shows the available slots number, occupied slots number and messages to guide vehicles to a parking slot. As the system is idle or busy, it changes the mode accordingly. Hence user can easily identify number of available slots without any ambiguity.
- **Wi-Fi Module (ESP8266)**: With this Wi-Fi module, the Parking system can talk to an external interface wirelessly. By using it, we can view the data in real time from anywhere. We can also check the availability of slots from afar or open the barrier gate manually if needed. This will provide convenience as we don't have to keep an eye on it all the time.
- **Power Supply**: All hardware components need a continuous power supply to function. The Arduino, sensors, display, and servo motor were powered through a regulated voltage supply.

B. Working of Hardware Components

The sensors scan the slots continuously and send signals to the Arduino. The controller receives signals from IR sensors and accordingly perform the calculations required to know the available slots at any instant.

Whenever any vehicle arrives at the entry point, entry sensor senses it and actuates the system. Arduino verifies the availability of slots and allows entry by sending control signal to servo motor. Gate opens and the vehicle enters, then the gate closes.

The LCD Display Updates the parking slots status as well as guiding the driver. The communication module transmits Sends the system status to mobile view, so that we can check the status of parking from anywhere.

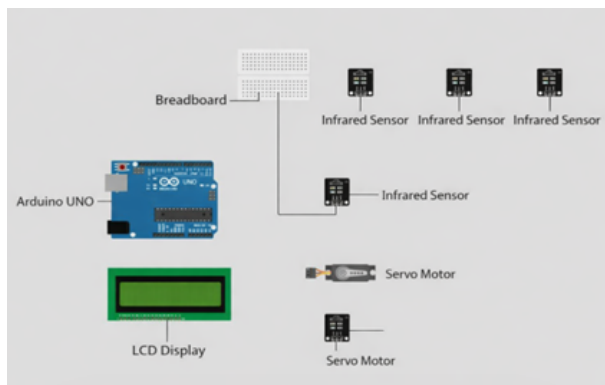


Fig. 3. Circuit Diagram of Smart Parking System

C. Advantages of Hardware Design

The proposed hardware design offers several advantages:

- Very simple and modular design.

- Utilizes low cost and readily available components.
- Stable operation and real time response.
- Can be interfaced with wireless networks.

V. SOFTWARE ARCHITECTURE

The software architecture diagram shows the logical view of smart parking system which includes software components and the relations between them. Following functions are implemented in software part of our proposed system: Embedded programming, Real time processing and Wireless communication for monitoring and control purpose.

A. Embedded System Programming

The logic of the program is created using embedded program through Arduino uno. It will read the input values from IR sensors and decode them. Based on the sensor information it will calculate the number of slots available and occupied.

Controller will check for multiple scenarios like Car detection, slot vacancy and gate movement. Gate will be opened only if slots are vacant and will remain close if parking lot is full. Also Timer control has been added for servo motors opening and closing.

B. Control Logic and Decision Making

The decision-making process is a key part of the software architecture. When the sensors detect that the vehicle is ready for entry at the entrance gate, then the availability of parking slots is checked by the system. If there are empty slots available, a signal controlling the opening gate system would be deployed, else denial message will be displayed denying entry into the parking.

Control Logic controls the states of Idle mode, Guidance mode, and capacity full mode. Depending on the states, system operation changes along with the display message system. The system reliability is enhanced with this methodology which keeps the operation systematic.

C. Display Management

LCD Display will be interfaced to the system through software that can control it according to requirement. In idle mode LCD display shall show the availability of all slots. When Car Arrival event happens system should go into Guidance Mode and shall display the count of available slots and some basic instructions.

Software will make sure that the LCD display shows the information corresponding to the data sensed at any moment. There should not be any lag between sensing of data and displaying the data on LCD. Proper formatting of messages is maintained to ensure clarity and ease of understanding for users.

D. IoT Dashboard Integration

It allows wireless communication using Wi-Fi module for remote monitoring and control of the system. The firmware of the device establishes connection with a mobile based dashboard where users can remotely check availability status of parking spaces.

system to sense more accurately in different lighting/weather conditions.

Improvements can be made by implementing guidance based navigation assistance on mobile phones inside the parking lot. Simple left and right signals can help guide drivers to their spot faster clearing internal traffic.

Moreover, this system can be optimized for electric vehicle parking slots by adding charging slots. Adding that feature would allow the system to cater to future transportation developments.

Other features that can be added are automatic billing and payments. The system can be integrated with identification RFID or licence plate number recognition in order to allow users to simply drive in, drive out and get billed.

In addition, the system can be integrated with a centralized monitoring platform to manage multiple parking locations from a single interface. This would be useful for large institutions and smart city applications.

Overall, the proposed system can be further developed into a more intelligent and fully automated parking solution by incorporating advanced sensing, data processing, and communication technologies.

VIII. CONCLUSION

In this paper, a smart car parking system based on embedded systems and wireless communication has been successfully designed and implemented. The system utilizes IR sensors to detect vehicle presence, an Arduino Uno for processing, a servo motor for automated gate control, and an LCD display for real-time user information. In addition, wireless communication enables remote monitoring and control, enhancing system accessibility.

The proposed system effectively addresses common parking challenges such as unnecessary vehicle entry, congestion, and lack of real-time information. By allowing entry only when parking space is available and providing clear guidance to users, the system improves overall parking efficiency and reduces traffic inside the parking area.

The test results are effective due to proper slot detection and faster response. Sensing controlling and communication modules work seamlessly making it easy to operate. Easy to operate system which is simple and inexpensive enough can be used for small or medium sized parking areas like school premises.

Project works successfully by implementing the ideas of embedded systems into real life. System may be improvised by adding more features and making it scalable.

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