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Automated Multi-Story Car Parking System Using IoT and Embedded Technologies for Efficient Space Utilization

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Abstract

Efficient parking management has become a pressing challenge in urban areas due to increasing vehicle numbers and limited parking spaces. This project introduces a Smart Multi-Story Car Parking System that leverages IoT and embedded systems to streamline parking operations. The system utilizes Arduino microcontrollers, stepper motors, RFID technology, and IR sensors to automate vehicle detection, slot allocation, and transport processes. Real-time status indicators and an intuitive software interface enhance user convenience while optimizing space utilization. Designed for urban infrastructure like malls, IT hubs, and multi-story parking structures, the system minimizes search time, eliminates unnecessary human intervention, and promotes efficient parking management with cost-effective and simple technology. This innovative solution offers a robust approach to addressing modern urban parking challenges. In this project, we propose a solution to effectively manage vehicle inflow and outflow within complex multi-story parking facilities. The system detects vehicles using IR sensors, provides real-time feedback, and automates parking space identification and allocation. With a straightforward design and minimal code complexity, this automated system finds and communicates parking slot availability efficiently, reducing both time and labour. Visual indicators guide users to the nearest available slot, ensuring a seamless experience. This system is ideal for high-traffic areas, reducing dependency on manual labour while delivering accuracy and convenience in parking operations.

INTRODUCTION

Urbanization has increased vehicle density, leading to parking shortages and inefficiencies in traditional parking systems. Multi-story parking facilities provide vertical space optimization but often lack the automation needed for ease of use. This project introduces an IoT-enabled, automated parking system to address these challenges, streamlining the process through RFID authentication, real-time availability tracking, and automated vehicle movement. The integration of IoT ensures system scalability, operational transparency, and user satisfaction.

There are two types of parking spaces: those reserved for specific individuals and free parking spaces available to everyone. Parking spaces reserved for specific individuals may be unoccupied if the person is on leave or absent from work. The

problem becomes apparent when the number of employees in an organization is greater than the number of parking spaces allocated to the organization. On the other hand, when the number of visitors exceeds the available parking spaces, visitors may park incorrectly, causing traffic congestion.

The daily parking problems can be summarized as shortage of designated parking slots for certain buildings, which is not enough for employees and visitors traffic congestion caused by visitors searching for parking slots. Incorrect parking where drivers park vehicles in a spot that is not designated for them. This could happen in a variety of settings, such as in a parking lot where each spot is assigned to a specific individual or in a public street where there are specific regulations about where and how long one can park.

The project entitled smart parking system is to manage all the parking facilities to a user. The recent growth in economy and due to the availability of low-price cars in the market, every average middle-class individual can afford a car, which is good thing, however the consequences of heavy traffic jams, pollution, less availability of roads and spot to drive the motor car. One of the important concerns, which is to be taken in accounting, is the problem of parking those vehicles. Though, if there is space for parking the vehicle but so much time is squandered in finding that exact parking slot resulting in more fuel intake and not also environment friendly. It will be a great deal if in some way we find out that the parking itself can provide the precise vacant position of a parking slot then it'll be helpful not limited to the drivers also for the environment.

Problem Statement

The current systems face limitations, including:

- Lack of real-time slot availability updates.
- Dependence on manual labour for slot allocation and car movement.
- Inefficient use of space due to human errors.
- Limited integration with digital solutions for seamless user experiences.

Proposed System

The proposed Smart Multi-Story Car Parking System automates parking and retrieval using a combination of Arduino microcontrollers, stepper motor-driven platforms, RFID readers, and IR sensors. Key features include:

A motorized entry tray for car transport to designated slots.

IR sensors to detect slot availability in real time.

LEDs for indicating slot status (red for occupied, green for available).

RFID authentication for secure slot allocation and retrieval.

Computer software for monitoring and managing parking operations.

LITERATURE REVIEW

[1] Multilevel Car Parking Systems with RFID and Automated Spot Detection

Multilevel car parking systems (MCPS) have emerged as efficient solutions to address the increasing demand for parking in urban areas. Early MCPS involved manual parking, but automation with systems like hydraulic lifts and conveyors improved space utilization RFID technology has revolutionized parking by enabling automatic vehicle authentication. RFID tags assigned to vehicles are scanned by readers, facilitating smooth entry and exit with enhanced security. Automated spot detection using IR sensors is crucial for optimizing space usage in MCPS. These sensors detect the presence of vehicles by measuring reflected infrared light, signalling spot occupancy to the system. This allows for real-time spot availability updates, reducing the time spent searching for parking.

Despite their advantages, challenges include high installation and maintenance costs, sensor accuracy issues, and space constraints in dense urban areas (Goswami & Sood, 2021). Future advancements are expected to integrate IoT, AI, and renewable energy solutions, improving system efficiency and sustainability. These technologies offer promising solutions for smart urban mobility and parking management.

[2] Prototype of an Automated Multilevel Car Parking System.

The paper presents the design and fabrication of a prototype for an automated multilevel car parking system. The system utilizes sensors, an Arduino Mega2560 microcontroller, and stepper motors to automate the parking and retrieval of vehicles. Light Dependent Resistors (LDRs) are used to detect the availability of parking spaces by measuring light intensity, sending data to the microcontroller for processing. The processed signals are sent to actuators, specifically stepper motors, which engage linear lead screws and gears to move the parking platform. The design aims to reduce space and time consumption compared to traditional parking systems, eliminating the need for manual operators. The system includes a flowchart outlining the stages of operation: parking, retrieving, sensor data processing, and actuator response. The proposed solution addresses issues such as limited space, time inefficiency, and the requirement for skilled operators in traditional systems, with potential applications in urban areas to alleviate parking difficulties. The hardware setup integrates mechanical and electrical components such as lead screws, stepper motors, and Arduino boards.

[3] IoT-Based Sensor-Enabled Vehicle Parking System

Dheeven et al. (2024) explore the development of an IoT-based smart vehicle parking system designed to alleviate traffic congestion in urban environments. The system integrates sensors with IoT technology to provide real-time data on parking space availability. Utilizing an ESP8266 WiFi module, the system sends parking status information to a web page, allowing users to view and reserve available slots remotely. The system is driven by infrared sensors, RFID technology, and GSM for notifications and billing. The vehicle's presence in the parking slot is detected, and the data is updated through IoT to ensure real-time availability tracking. The billing is managed based on the time the vehicle is parked, and users are notified via SMS for payment. The research emphasizes the reduction in time spent searching for parking, thus alleviating urban traffic issues. Additionally, the system's ability to autonomously track vehicle presence and automatically update availability, alongside the integration of a user-friendly interface for parking management, makes it an innovative solution for smart cities and urban mobility challenges.

[4] Smart car parking system for smart cities using IoT

The paper discusses the development of a smart car parking system aimed at addressing parking inefficiencies in urban areas through Internet of Things (IoT) technology. With the increase in vehicle numbers, finding an available parking space has become a significant challenge in metropolitan areas. The authors propose an IoT-based system that provides real-time parking availability and reduces the user's time spent searching for an open spot. The system uses sensors to detect parking space occupancy and sends data to a cloud server, allowing users to receive parking updates via a mobile application. Additionally, it uses algorithms to suggest the optimal parking spot based on proximity and availability, enhancing both user convenience and efficiency. The implementation of the system can significantly reduce traffic congestion and energy consumption by guiding users to available spots promptly. Furthermore, the paper highlights the importance of security features in smart parking systems, including the use of wireless communication and sensors for monitoring. The authors suggest that such systems not only improve parking management but also contribute to environmental sustainability by reducing unnecessary emissions from vehicles searching for parking. The proposed solution offers a cost-effective and user-friendly approach, aligning with the growing demand for smart city technologies.

[5] Prototype of RFID-based parking slot availability detection system

The concept of RFID-based parking systems has gained significant attention due to the growing demand for efficient parking solutions in urban areas. Lindawati et al. (2020) proposed a prototype for RFID-based parking slot availability detection, aimed at improving the parking experience in multi-storey parking structures. Their system utilizes Arduino Mega, RFID tags, RFID readers, and photodiode sensors to automate the detection of available parking slots. RFID tags, attached to vehicles, communicate with the system at the parking entrance, allowing for seamless slot assignment and automatic updates to the availability status.

Previous research, such as Bassam & Samann (2020), explored the use of Optical Character Recognition (OCR) and IoT technologies to provide parking availability information, highlighting the potential of integrating advanced sensors and cloud-based monitoring. Additionally, Hidayat et al. (2020) implemented proximity inductive sensors to enhance real-time detection of parking slots, integrating IoT systems to relay data to centralized platforms for user access.

These studies underscore the growing trend toward automated, RFID-based solutions for parking management, offering not only time and fuel efficiency for drivers but also reducing congestion in urban parking lots. However, challenges remain in terms of system scalability and real-time data processing, suggesting a need for further refinement and optimization of such systems.

METHODOLOGY AND WORKING PRINCIPLE

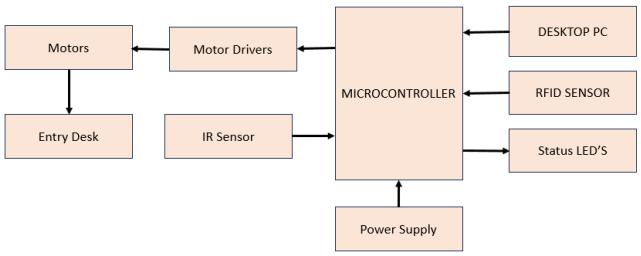

Fig 1: Block Diagram

The Smart Multi-Story Car Parking System follows a structured methodology to ensure efficient parking and retrieval operations using automation and IoT technologies. The process begins with system initialization, where the Arduino microcontroller activates all components, including IR sensors, the RFID module, motors, and status LEDs. The computer interface retrieves real-time parking slot availability and syncs with the database.

During the parking process, users check slot availability through the software interface or by observing the status LEDs, where a green LED indicates an available slot and a red LED signifies an occupied one. The user then places their car on the motorized entry tray and scans their RFID token. The Arduino reads the RFID input and identifies an available slot using IR sensor data. The system assigns the slot, updates its status to "booked," and

changes the corresponding LED from green to red. The Arduino then controls the stepper motors to move the tray along the X, Y, and Z axes: the X-axis aligns the tray with the designated slot, the Z-axis adjusts the vertical position for multi-story parking, and the Y-axis moves the car into the assigned slot. Safety mechanisms, such as limit switches, prevent misalignment and collisions.

For the unparking process, the user scans their RFID token at the exit station, prompting the system to identify the vehicle's assigned slot from the database. The Arduino commands the stepper motors to retrieve the car, moving the tray in reverse order to return the vehicle to the entry tray. Once the car is retrieved, the database updates the slot status to "available," and the red LED turns green, indicating the slot is free for the next user.

The system is continuously monitored through the computer software, which tracks slot statuses, motor activity, and potential errors. All parking and unparking transactions are logged for audits and troubleshooting. This structured methodology ensures an automated, secure, and user-friendly parking experience while optimizing space utilization and minimizing manual intervention.

FLOWCHART PROJECT

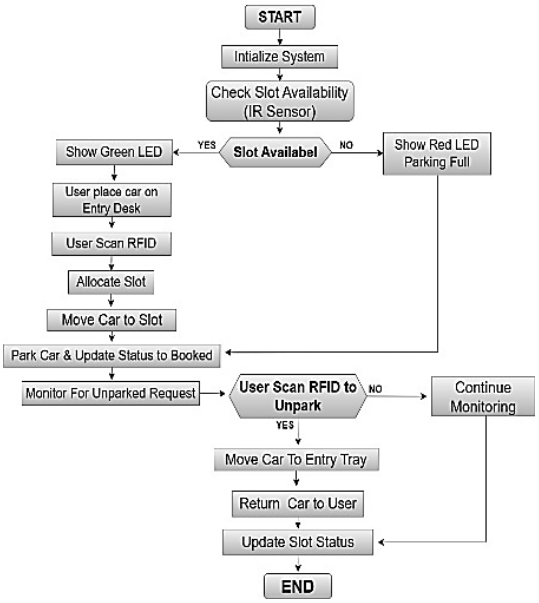

Fig 2: Flowchart Project

The system begins with initialization, where all hardware components, including the Arduino microcontroller, stepper motors, RFID reader, IR sensors, and status indicators, are powered on and activated. Once the system is operational, it continuously checks slot availability using IR sensors installed at each parking slot. Based on the sensor feedback, a green LED lights up if a slot is available, while a red LED indicates that all slots are occupied.

In the car parking process, if a parking slot is available, the user places their car on the entry tray and scans their RFID card at the entry station. The system assigns a slot, updates its status to "booked," and activates the stepper motors to move the entry tray to the designated parking slot. Once the car is securely parked, the tray returns to its original position, ready for the next vehicle.

For the unparking process, the system continuously monitors for any retrieval request. When a user scans their RFID card for unparking, the system identifies the slot where the car is parked. The stepper motors then move the tray to the assigned slot, retrieve the car, and return it to the entry platform. The slot status is updated to "available," and the green LED is illuminated, indicating that the space is free for the next user.

Throughout its operation, the system remains in a continuous monitoring state, tracking parking and unparking requests while updating slot availability in real time. This cycle repeats until the system is powered off, ensuring a seamless and automated parking experience.

TECHNOLOGIES USED

Embedded Systems:

- Arduino Microcontroller: Serves as the central control unit for the system, processing sensor inputs and controlling motor operations.
- Stepper Motor and Driver: Enables precise control of tray/platform movement to transport vehicles to assigned parking slots.
- Radio Frequency Identification (RFID) Technology
- RFID Reader and Tags: Used for vehicle identification, slot allocation, and parking status management. Each user is issued a unique RFID token linked to a specific parking slot.
- Infrared (IR) Sensor Technology
- IR Sensors: Detect the presence or absence of a vehicle in each parking slot. These sensors provide real-time feedback to determine slot availability.

Status Indicator System

- LED Indicators: Visual indicators that provide real-time parking slot status:
- Green LED: Indicates available slots.
- Red LED: Indicates that the parking slot is occupied.

IoT Integration

- Computer Software Interface: Displays booking status, monitors parking operations, and provides an overview of slot availability.
- Cloud Integration (Optional): Data logging for parking operations and remote monitoring of system performance.

Motor Control Mechanism

- Tray/Platform System: Controlled by stepper motors, it moves vehicles between the entry point and assigned slots for parking or retrieval.

- Multi-Motor Coordination: Ensures precise and synchronized movement of the tray for efficient car placement.

Automation and Real-Time Control

- Sensors and Microcontroller Integration: Ensures automated and error-free operation by synchronizing sensor data with motor actions.
- RFID Scanning: Automates slot allocation and retrieval without manual intervention.

User Interface Components

- LCD/Software Display: Shows slot allocation, parking confirmations, and system alerts.
- Buzzer (Optional): Provides audible alerts for errors or system notifications.

This combination of technologies allows for an efficient, scalable, and fully automated parking solution suitable for urban environments with high vehicle density.

RESULT & DISCUSSION

At present some countries have portals which users can gain information about parking areas via the internet. This system can give users the information about parking space, but it won't be able to give which parking slot is vacant and occupied. Hence, such a system cannot smartly handle the issue. Car lifts along with an automated robotic system, which automatically takes the car to a particular parking spot as soon as the car enters on a platform. This system cannot be installed by medium scale shopping malls, movie theatres as it can cost them a huge amount. At many public places, the system only shows the availability but it cannot show the exact slot and path to the slot available. Hence, there is the need to smartly find the path to the vacant spot.

Fig 3: Flowchart Project

The number of IR sensors and parking slots in your project depends on the system design and the specific scale you wish to implement.

IR Sensors Involved: One IR sensor per parking slot is typically required to detect vehicle presence. Additional sensors may be placed at entry and exit points for better system accuracy and control.

Example Calculation for a Prototype System:

If you have a three-level parking structure with 4 slots per level, you would require:12 IR sensors (one for each parking slot).

If additional sensors are placed at: Entry tray (1 sensor) and exit tray (1 sensor), you may need a total of 14 IR sensors for the complete system.

Parking Slots Involved:

The number of slots depends on the available space and intended capacity. Common configurations can range from 10 to 100+ slots depending on system size.

APPLICATIONS AND ADVANTAGES

Applications:

Urban multi-story parking facilities.
Shopping malls, airports, and public spaces.
Office complexes with limited parking spaces.

Advantages:

Optimized use of vertical space.
Automated and user-friendly operation.
Real-time updates on slot availability.
Reduced human intervention, errors, and time delays.

CONCLUSION

The Smart Multi-Story Car Parking System offers a technologically advanced solution to urban parking challenges. The concepts of smart cities have always been a dream. There have been advancements made from the past couple of years to make smart city dream to reality. The advancement of internet of things and cloud technologies has given rise to the new possibilities in terms of smart cities. Smart parking facilities have always been the core of constructing smart cities. The system provides a real time process and information of the parking slots.

By integrating IoT and automation, the system enhances efficiency, reduces user frustration, and optimizes resource utilization. With its scalable design and ease of implementation, the project has the potential to revolutionize parking infrastructure in urban areas.

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