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RFID Based Automatic Stackable Car Parking System

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Abstract

The increasing number of vehicles and limited parking spaces in urban areas have made efficient parking management a pressing challenge. This project proposes a Smart Multi-Story Car Parking System that leverages lot 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, this system minimizes search time, eliminates unnecessary human intervention, and promotes efficient parking management with cost-effective and simple technology. RFID-based automatic stackable car parking system, designed to optimize parking space utilization and reduce congestion in urban areas. The system utilizes RFID technology to identify vehicles, automate parking slot allocation, and facilitate efficient vehicle retrieval. A stackable parking mechanism enables maximum space utilization, while a user-friendly interface provides real-time parking availability and guidance. The proposed system aims to reduce parking time, minimize manual intervention, and enhance overall parking experience. Experimental results demonstrate the effectiveness and efficiency of the proposed system, making it a promising solution for modern urban parking challenges.

INTRODUCTION

The relentless surge of urbanization has precipitated a critical challenge: escalating vehicle density coupled with the inherent limitations of traditional parking infrastructure. This confluence of factors has resulted in pervasive parking shortages, operational inefficiencies, and heightened user frustration, particularly within multi-story parking facilities where vertical space utilization is often suboptimal due to the absence of intelligent automation. This paper presents the development and evaluation of an IoT-enabled, automated stacked parking system designed to address these pressing concerns. The proposed system leverages Radio-Frequency Identification (RFID) for secure user authentication, enabling a seamless and efficient parking experience. Real-time availability tracking, facilitated by an integrated sensor network, provides dynamic information regarding parking slot occupancy, optimizing space utilization. Furthermore, the system incorporates automated vehicle movement mechanisms, minimizing human intervention and streamlining the parking process. A key innovation lies in the system's ability to differentiate between reserved and free parking spaces, dynamically managing allocation based on user identity and availability. This is particularly crucial in environments where designated parking slots may remain vacant due to employee absences or visitor fluctuations, leading to inefficient space utilization and potential congestion.

The problem addressed by this research is multifaceted. Firstly, the inherent disparity between the number of designated parking slots and the fluctuating demand from employees and visitors leads to chronic shortages. Secondly, the lack of real-time information and automated guidance results in prolonged search times, increased fuel consumption, and exacerbated traffic congestion. Finally, the prevalence of incorrect parking, whether due to misidentification of available slots or disregard for designated areas, further compounds these issues. Such challenges are not limited to specific locations but are prevalent in various urban settings, including corporate campuses, commercial complexes, and public parking structures.
This paper details the design, implementation, and performance evaluation of the smart stacked parking system. By integrating IoT technologies, this system aims to revolutionize parking management, offering a scalable, transparent, and user-centric solution. The findings demonstrate the potential of automated parking systems to significantly enhance parking efficiency, reduce congestion, and improve the overall user experience, contributing to sustainable urban mobility.

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 a solution to address the growing demand for parking in urban areas. Initially, MCPS relied on manual parking, but the introduction of automation through hydraulic lifts and conveyors significantly improved space utilization. The integration of RFID technology has further revolutionized parking by enabling automatic vehicle authentication, where RFID tags assigned to vehicles are scanned by readers, facilitating smooth entry and exit with enhanced security. Additionally, automated spot detection using IR sensors optimizes space usage by detecting the presence of vehicles and providing real-time spot availability updates, reducing the time spent searching for parking. Although MCPS offers several advantages, challenges such as high installation and maintenance costs, sensor accuracy issues, and space constraints in dense urban areas persist. However, future advancements are expected to integrate IoT, AI, and renewable energy solutions, improving system efficiency and sustainability, and offering promising solutions for smart urban mobility and parking management.

[2] Prototype of an Automated Multilevel Car Parking System.
This paper presents a prototype for an automated multilevel car parking system, designed to optimize space and time efficiency. The system utilizes sensors, an Arduino Mega2560 microcontroller, and stepper motors to automate parking and retrieval processes. Light Dependent Resistors (LDRs) detect parking space availability by measuring light intensity, sending data to the microcontroller for processing. The processed signals then activate stepper motors, which move the parking platform using linear lead screws and gears. The design eliminates manual operators, reducing space and time consumption compared to traditional parking systems. A flowchart outlines the system's operation stages, including parking, retrieving, sensor data processing, and actuator response. This solution addresses issues like limited space, time inefficiency, and the need for skilled operators, offering potential applications in urban areas to alleviate parking difficulties.

[3] IoT-Based Sensor-Enabled Vehicle Parking System
Dheeven et al. (2024) propose an IoT-based smart vehicle parking system to alleviate urban traffic congestion. The system combines sensors and IoT technology to provide real-time parking space availability data. Using an ESP8266 WiFi module, the system updates a web page with parking status information, allowing users to remotely view and reserve available slots. Infrared sensors, RFID technology, and GSM enable vehicle detection, notifications, and billing. The system tracks vehicle presence, updates availability in real-time, and manages billing based on parking time, with users receiving payment notifications via SMS. This research highlights the system's potential to reduce

parking search times, alleviating urban traffic issues. Its innovative features, including autonomous vehicle tracking and user-friendly parking management, make it a promising solution for smart cities and urban mobility challenges.

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

The paper presents a smart car parking system that leverages Internet of Things (IoT) technology to address parking inefficiencies in urban areas. With the rising number of vehicles, finding parking has become a significant challenge. The proposed system provides real-time parking availability, reducing search time, and guiding users to optimal spots using sensors, cloud servers, and mobile applications. This not only enhances user convenience but also reduces traffic congestion and energy consumption. The system prioritizes security, incorporating wireless communication and sensors for monitoring. By reducing unnecessary emissions from vehicles searching for parking, the system contributes to environmental sustainability. The proposed solution offers a cost-effective and user-friendly approach, aligning with the growing demand for smart city technologies and improving parking management.

[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. Researchers have proposed various prototypes to improve the parking experience in multi-storey parking structures. For instance, Lindawati et al. (2020) developed a system using Arduino Mega, RFID tags, RFID readers, and photodiode sensors to automate parking slot availability detection. This system allows for seamless slot assignment and automatic updates to the availability status. Other studies have explored the use of Optical Character Recognition (OCR), IoT technologies, and proximity inductive sensors to provide parking availability information and enhance real-time detection of parking slots. These studies demonstrate the growing trend toward automated, RFID-based solutions for parking management, offering benefits such as time and fuel efficiency for drivers and reduced congestion in urban parking lots. However, challenges remain in terms of system scalability and real-time data processing, highlighting the need for further refinement and optimization of these systems.

METHODOLOGY AND WORKING PRINCIPLE

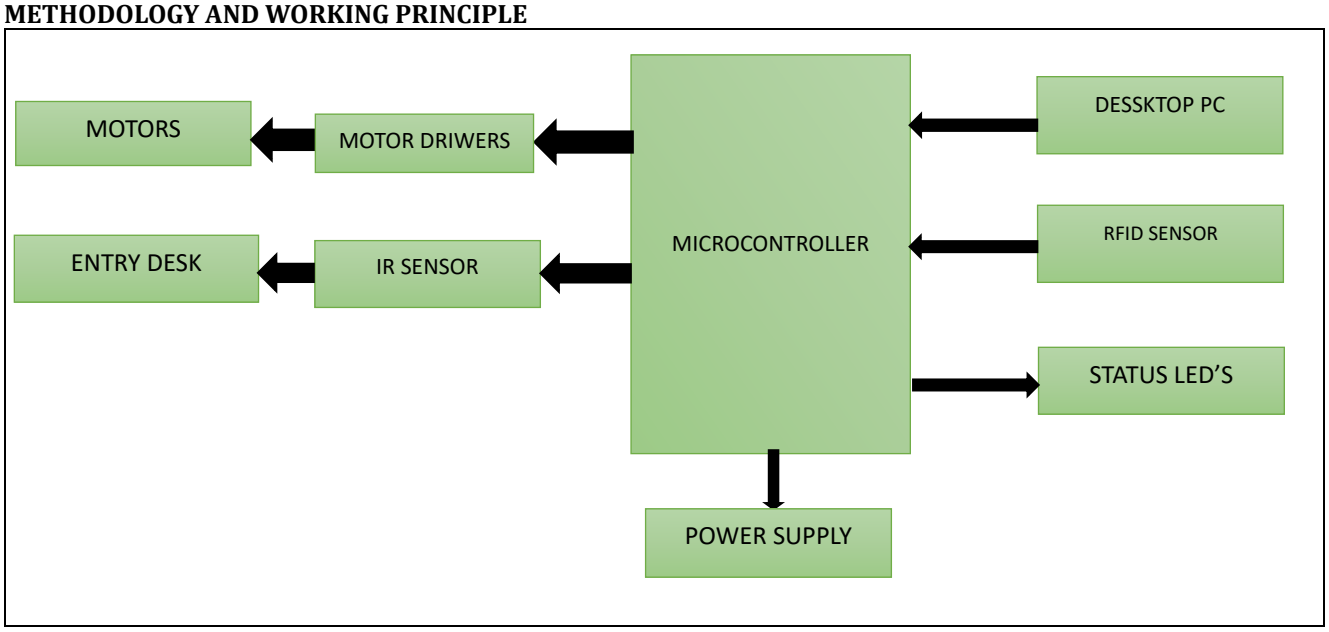

Fig 1: Block Diagram

The Smart Multi-Story Car Parking System utilizes automation and IoT technologies to ensure efficient parking and retrieval operations. The system initializes with the Arduino microcontroller activating components such as IR sensors, RFID modules, motors, and status LEDs.

Users check parking slot availability through software or status LEDs, and upon selecting a slot, they scan their RFID token. The Arduino assigns the slot, updates its status, and controls stepper motors to move the car into the assigned slot. Safety mechanisms prevent misalignment and collisions. For unparking, the user scans their RFID token, prompting the system to retrieve the car. The system continuously monitors slot statuses, motor activity, and potential errors, logging all transactions for audits and troubleshooting. This structured methodology provides an automated, secure, and user-friendly parking experience, optimizing space utilization and minimizing manual intervention.

FLOWCHART PROJECT

The system begins with initialization, powering on and activating all hardware components, including the Arduino microcontroller, stepper motors, RFID reader, IR sensors, and status indicators.

Once operational, the system continuously checks parking slot availability using IR sensors, indicating available slots with green LEDs and occupied slots with red LEDs. During parking, a user scans their RFID card, and the system assigns a slot, updates its status, and moves the entry tray to the designated slot using stepper motors.

After parking, the tray returns to its original position. For unparking, the system monitors for retrieval requests, identifies the slot, and retrieves the car using stepper motors, updating the slot status to "available" and illuminating the green LED.The system remains in a continuous monitoring state, tracking requests and updating slot availability in real-time, ensuring a seamless and automated parking experience.

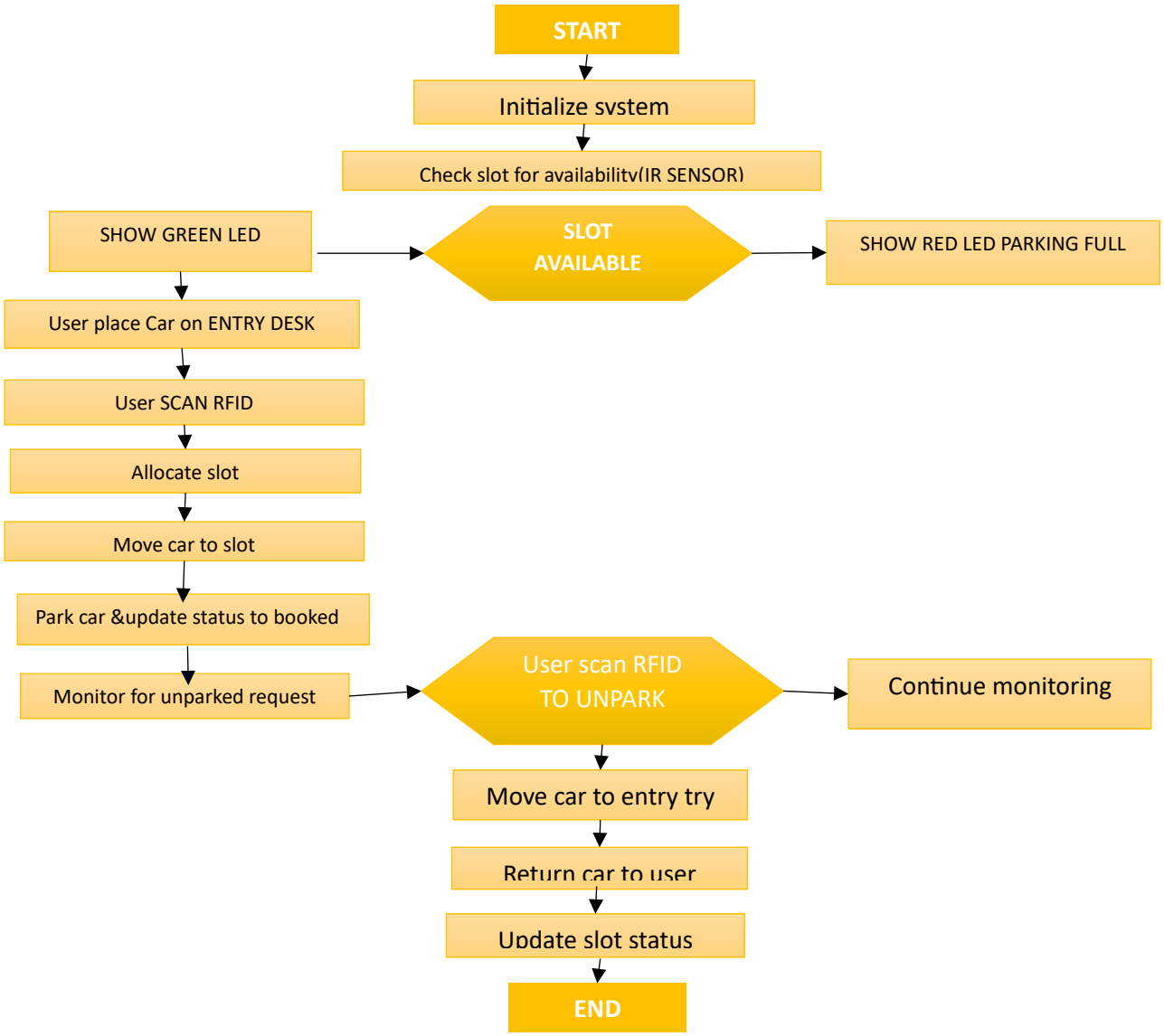

Fig 2: Flowchart Project

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

Currently, some countries have online portals that provide information on parking areas, but these systems cannot specify which individual parking slots are vacant or occupied.

To address this issue, a smart parking system is needed. Existing automated robotic systems that use car lifts to park vehicles are expensive and not feasible for medium-scale establishments like shopping malls or movie theaters.

Most public parking systems only display availability without providing the exact location and path to the vacant spot. To overcome these limitations, a smart parking system with IR sensors can be designed to detect vehicle presence and guide users to available parking slots.

Fig 3: Flowchart Project

The number of IR sensors required depends on the system design and scale, with at least one sensor per parking slot, and additional sensors at entry and exit points for improved accuracy.

For example, a three-level parking structure with 4 slots per level would require 12 IR sensors, plus additional sensors at entry and exit points, totaling 14 sensors.

The number of parking slots depends on the available space and intended capacity, ranging from 10 to over 100 slots.

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 represents a significant step towards realizing the concept of smart cities. Recent advancements in Internet of Things (IoT) and cloud technologies have brought this vision closer to reality.

Smart parking facilities are a crucial component of smart cities, and this system provides real-time information on parking slot availability. By integrating IoT and automation, the system enhances efficiency, reduces user frustration, and optimizes resource utilization.

Its scalable design and ease of implementation make it a potential game-changer for parking infrastructure in urban areas, offering a technologically advanced solution to urban parking challenges.

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