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Smart Parking System

Mr. Suyog Pradip Sawant, Durva Pednekar, Arpita Buchade, Rutuja Ugvekar, Manasi Joshi
SSPM's college of Engineering, Kankavli

Abstract: Rapid growth in city population accompanied by a vivid pace of urbanization has transformedparking systems within cities into such complex entities. Whereas parking systems generally devour considerable portions of time, ineffectively utilize available space, and invariably maximize traffic queues; all these matter not only for the irritation of drivers but also for environmental concerns like air pollution and consumption of plenty of fuel. The issues include no real-timeinformation on parking space availability, security on safety of the cars, and the others. To solve these problems, it proposes a smart parking solution based on Internet of Things technologies such as RFID sensors, cameras, and mobile applications to optimize parking space utilization, enhance user experience, and promote sustainable urban mobility. The proposed solution integrates real-time data analytics into the automated payment system, giving rise to an efficient and user-friendly as well as environmentally responsible parking management system. It has been found that the parking system could improve air quality and reduce congestion highly if it is implemented. At the end, this study contributes to the debate of smart city projects and innovative techniques.

INTRODUCTION

Cities are growing at the pace of rapid urbanization, and with this, the issues of efficient parking operations are getting challenging to handle. The rapid entry of automobiles in most urban areas has outpaced the development of adequate infrastructures for parking. This scenario characterizes most traditional parking systems as inefficient ones. Those inefficiencies come in form, such as wasted time and resources-dangling cons that contribute to increased traffic congestion and environmental degradation. It makes driving a lot of time wasted lookingfor parking. It is frustrating, does contribute to more wasteful fuel consumption and emission. Studies have already shown that much of urban traffic is created by motorists searching for a parking space and accelerating congestion, and in some cases, pollution levels. In addition, the absence of real-time parking availability information would mean faster acceleration toward bad choices and faster acceleration of congestion. Most of the motorists are left to their fate by the use of archaic signs or guessing, which leads to frustration and, more importantly, delays. Aside from these operational challenges, there has been a long-standing security concern: namely, the issue of vehicle safety. Most parking facilities are not well- equipped with surveillance and monitoring, thus leaving the faculties to be vulnerable to theft and vandalism. Apart from that, dependency on cash collection through human contribution can be inefficient and lead to loss in revenue for parking operators and also less convenient forthe users. This paper introduces a Smart Parking System based on IoT technologies that apply sensors, cameras, and mobile applications. The innovative solution aims to transform parking management systems into smart, efficient, and sustainable systems that enhance users' experiences, while providing developmental leads to the development of even smarter cities. This proposed system will use real-time data and analytics to communicate very effective, minute- by-minute updates on the availability of parking spaces, prices, and locations, thus streamliningthe parking process and reducing search time. Additionally, the integration of automated pay- ment systems can enhance convenience and security for users, making the overall experience more user-friendly. Technology for better living in towns.

LITERATURE REVIEW

The literature on smart parking systems highlights various approaches and technologies thathave been developed to improve parking management. For instance, Roja D. (2024) analyzed RFID sensors in parking space occupancy monitoring, which proved that the inclusion of RFIDtechnology enhances the readability of parking spaces and informs users well in advance aboutthe availability on time [T5]. This procedure does not only make parking process more stream-lined but saves tremendous time, the usage of which used to take for hunting or searching the vacant parking space, thus utilizing urban environment resources better in use. Savan K. Vachani Dhaval, 2018 performed an elaborate analysis of several algorithms usedby WSN in smart parking systems. Their research was based on the analysis of various algorithms such as First Come-First-Serve (FCFS), Priority (PR), Round Robin (RR), and several other algorithms to establish the efficiency, accuracy, and reliability of algorithms in managingparking resources [T5]. From their analysis, it can be concluded that the choice of the algorithm is necessary to ensure maximum utilization of parking space and enhancing user satisfaction. Through comparison in performance, the study is able to identify more useful strategies in termsof applying improvement for efficiency in smart parking systems. Andrea Sant et al. (2020) designed and proposed a smart parking system: Pay-As-You-Go system based on geospatial data and the Google Maps JavaScript API with regard to real-timeupdates for users about availability and prices for parking. The web application that their teamdesigned achieved high performances for the effective integration of technology into optimizing user experience and operational performance [T4]. In addition to the convenience of retrieving one's parked vehicle, dynamic pricing according to demand can also form an optimal tool in rationally employing car park resources. Pampa Sadhukhan, in her 2017 dissertation, also introduced an e-parking system using ultrasonic sensors and cameras for real-time monitoring and management of parking spaces. The results show a sharp decline in traffic congestion and air pollution, thus elaborately demonstrate the environmental benefits while deploying smart parking solution [T2]. The latest sensors ascertain the rapid detection of occupancy of the parking places by permitting smarter resource management in order to contribute towards having a more sustainable environment for a city. All the literature supports that there are grand potentials for IoT technologies to revolutionize parking management with scalable innovative solutions that set the scene for a smarter urban environment. Summarily, integration with a wide variety of technologies improves the performance of parking systems and supports the broader objectives of sustainability and quality of life in an urban environment. With increasingly populated cities, the demand for smart parking solutions will be greater to overcome issues related to increasing vehicle populationsand effective urban mobility.

RESEARCH GAPS

Technology Integration and Scope: Project 1 uses both NPR and RFID, offering a broader range of security and access control features compared to Project 2, which focuses more on RFID and infrared sensors. Exploring the integration of NPR with RFID in Project 2 could enhance its security and accuracy.

Performance and Accuracy: Project 1 reports high performance metrics (100 percent age RFID accuracy, 95 percentage NPR accuracy), while Project 2 does not specify detailed accuracy metrics. Investigating how the performance of RFID and infrared sensors in Project 2compares to the NPR technology in Project 1 could provide insights into optimizing the accuracy and robustness of the system.

User Experience and Usability: Project 1 includes user feedback and ratings (4.2 stars), highlight- ing its usability. Project 2 lacks detailed usability feedback. Analyzing user experience and satisfaction in Project 2, and comparing it with Project 1, could identify areas for improvement in the user interface and overall system design.

System Efficiency and Scalability: Project 1 demonstrates effectiveness in a real-world scenario, while Project 2 focuses on system design but lacks detailed scalability analysis. Researching the scalability of the Project 2 system for larger parking facilities could provide insights into its effectiveness and efficiency in various environments.

Security and AntiPassback Features: Project 1 incorporates anti-passback mechanisms, while Project2 does not mention similar security features. Investigating and implementing anti-passback mechanisms in Project 2 could enhance its security and prevent unauthorized access.

PROBLEM STATEMENT

Parking congestion is a significant issue in urban areas, causing frustration for drivers and leading to increased fuel consumption, pollution, and wasted time. Traditional parking management systems are often inefficient, lacking real-time monitoring, effective space allocation, and automated guidance, making it difficult for drivers to find available parking spots quickly and easily. This leads to unnecessary circling and traffic congestion, particularly in high-demand areas. The Smart Parking System aims to address these challenges by developing an automated and integrated solution that can provide real-time data on parking availability, enable seamlessreservations, automate the entry and exit process, and offer convenient payment options. The solution should also support data analytics for optimizing space usage, dynamic pricing, and providing insights for future urban planning. By implementing a smart parking system, cities can reduce traffic congestion, enhance theuser experience, and promote a more sustainable and efficient use of parking resources.

PROPOSED SYSTEM

Analysis/Algorithms

Augmented Reality (AR) Guidance: Enhance the user experience: Use AR to overlay parking space availability directly onto the driver's view: This involves utilizing augmented reality technology to display real-time information about available parking spaces on the driver's wind- shield or smartphone screen. For instance, as a driver approaches a parking area, the AR systemcould highlight available spots in their line of sight, making it easier to find a space without having to search manually. Simplify navigation: Provide turn-by-turn directions to available parking spots: The AR system can also guide the driver directly to the nearest available parking space by offering step-by-step navigation. This could be displayed on the driver's windshield or a mobile device, similar to how GPS systems provide directions but with a focus on find- ing parking spots. 2. Advanced Security Features: Enhance data privacy: Protect user data with robust security measures: In addition to physical security, the system should implement strong cyber security protocols to safeguard user data. This could include encryption, secure storage, and compliance with data protection regulations to ensure that personal information, like payment details or biometric data, is not compromised. 3. Social Sharing and Community Engagement: Create a parking community: Allow users to share parking tips, recommendations, or experiences: The system could include a social component where users can interact with each other by sharing useful information about parking. For example, users could leave reviews or tips about specific parking areas, recommend spots based on proximity to certain locations, or share experiences to help others make informed decisions. This could foster a sense

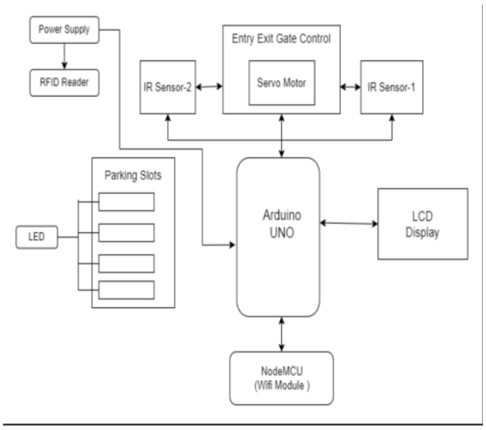

Figure 1: Proposed System

SYSTEM DESIGN

COMPONENTS: IR sensor 1, servo motor, Ultrasonic Sensor, Camera, Theft detection unit, parking slot, IR Sensors (1-3), RFlD Reader NodeMCU ESP 8266, User interface and Communication End user cloud server, Addition Components, Arduino UNOBuzzer, LED, Power supply, 24 x4 LCD display, 12C module for the LCD

- Hardware Components: Sensors: - Ultrasonic sensors for parking space detection - Infrared sensors for vehicle detection - Camera modules for license plate recognition (optional) Microcontrollers: - Arduino or Raspberry Pi boards for sensor integration and data processing. Communication Modules: - Wi-Fi or cellular modules for data transmission to the cloudor server. Display and User Interface: - LED displays or mobile apps for users to access parking information. Power Supply: - Battery or solar-powered systems for sensors and microcontrollers

- Software Components: Operating System: - Windows IoT for microcontrollers, Programming Languages: - C, C++, or Java for sensor integration and data processing, Data Analytics Platform: - Cloud-based platforms like AWS IoT, Google Cloud IoT Core, or Microsoft Azure IoT Hub. Website Development: - Website development for user interface and parking management. Database Management: - Relational databases like MySQL for data storage. Network and Connectivity Components: Internet Connectivity: - Wi-Fi networks for data transmission. Cloud Services: - Cloud-based platforms for data analytics, storage, and processing. API Integration: - APIs for payment gateways, mapping services, or other third-party integrations. Other Components: Parking Management Software: - Custom-built or third-party software for parking space allocation and management. Security and Surveillance: - CCTV cameras and security systems for parking area monitoring. Power Backup: - Battery backup systems for sensors and microcontrollers.

1.1 Methodology: Requirements Analysis: Identify parking challenges and user needs: This initial phase involves understanding the specific problems faced by users when it comes to parking. Challenges might include difficulties in finding available spaces, long search times, or inefficient payment systems. User needs could involve real-time availability updates, easy navigation to parking spots, or secure payment options. Gathering this information is critical to designing a system that effectively addresses these issues. System Design: Sensors: Choose and place sensors to detect parking space availability: The design phase begins with selecting the appropriate types of sensors, such as ultra- sonic, infrared, or camera-based sensors, that will be used to detect whether parking spaces are occupied or free. The placement of these sensors is crucial for accurate detection, and they should be strategically positioned in each parking spot to monitor the status reliably. Communication: Implement wireless protocols for data transmission: This step involves setting up a communication network that allows the sensors to transmit data about parkingspace occupancy to a central system. Wireless protocols like Wi-Fi, Zigbee, or LoRaWAN could be employed depending on the scale and environment of the parking area. These protocols ensure that data is transmitted efficiently and in real-time. Data Processing:

Analyze data to monitor space occupancy: The data collected by the sensors needs to be processed to determine which spaces are occupied and which are available. This analysis might involve filtering out false positives, aggregating data for trends, or integrating it with other data sources, such as vehicle entry and exit logs. This processed data is then used to update the system in real-time. User Interface: Develop a mobile app or web platform for real-time information and reservations: To make the system accessible to users, a user interface is developed, typically in the form of a mobile application or a web platform. This interface allows users toview real-time information about available parking spaces, make reservations, navigate to their selected spot, and potentially pay for parking. The design should be user-friendly,ensuring that information is easily accessible and actionable. Integration and Testing: Backend: Set up server and cloud storage for data management:The integration phase involves setting up the backend infrastructure, including servers and cloud storage, to manage the vast amounts of data generated by the sensors. The backend system should be robust, scalable, and secure, ensuring that it can handle real-time data processing and storage efficiently. Testing: Validate system accuracy and performance: Finally, the system undergoes rigorous testing to ensure it functions as intended. This includes testing the accuracy of the sensors in detecting parking occupancy, the reliability of data transmission, the responsiveness of the user interface, and the overall system performance under various conditions. Any issues identified during testing are addressedbefore the system is deployed for public use.

IMPLEMENTATION

Hardware:

Sensors: Detects vehicle presence: These sensors are responsible for determining whethera park ing spot is occupied or available. Various types of sensors can be used, such as ultrasonic sensors, infrared sensors, or magnetic sensors. They detect the presence of a vehicle and send this information to the microcontroller.

Microcontroller: Manages sensor data: The microcontroller acts as the central processingunit that gathers data from the sensors. It processes this data to determine the statusof each parking spot and then sends this information to the communication module for further transmission.

Communication: Wi-Fi/LoRa/Zigbee: The communication module handles the transmis-sion of data from the microcontroller to the cloud server. Wi-Fi is suitable for smaller areas with existing infrastructure, while LoRa and Zigbee are better for larger areas due to their low power consumption and long-range capabilities.

Software:

Cloud Platform: Data processing and storage: The cloud platform is where the data fromthe sensors is stored and processed. It analyzes the data to determine the availability of parking spots in real time and makes this information accessible to users through the app. App: Real-time parking info, reservations, payments: The user-facing application pro- vides real-time updates on parking availability, allows users to make reservations, and facilitates payment for parking. This app can be accessed via smartphones, offering a convenient interface for managing parking.

Backend: Handles user data, spot management: The backend system supports the app andcloud platform by managing user accounts, processing payments, and handling parking spot reservations. It ensures that all user interactions with the app are secure and efficient.

Data Flow:

Sensors → Microcontroller → Cloud Server → User App: This represents the flow of data in the system: Sensors detect the presence of vehicles and send this data to the microcontroller. The microcontroller processes the sensor data and transmits it to the cloud server via the communication module. The cloud server stores and processes this data, making it available for the user app.

The user app retrieves the processed data from the cloud server, displaying real-time parking information to users and allowing them to interact with the system. Testing and Deployment: Testing: Unit and system testing, UAT: Before deployment, the system undergoes various testing stages. Unit testing involves testing individual components, such as sensors and microcontrollers. System testing ensures that all components work together seamlessly. User Acceptance Testing (UAT) involves real users testing the system to validateits usability and functionality. Deployment: Pilot run, full deployment, ongoing monitoring: The deployment phase begins with a pilot run, where the system is tested in a controlled environment to identifyany issues. After successful testing, the system is fully deployed across the desired area. Ongoing monitoring ensures that the system continues to operate effectively, and any issues are addressed promptly.

2. Experimental Setup: Details About Input to Systems

Vehicle Detection Data: Input from IoT sensors (e.g., ultrasonic, infrared) installed in parking spots to detect vehicle presence. Input from cameras with ANPR for vehicle identification at entry/exit points.

User Input: User requests for parking spot availability through the mobile app or web interface. Reservations and booking confirmations made by users via the system.

Payment Data: Input from online payment gateways (Google Pay, Net Banking) for parking fee transactions. System Administrator Input: Manual overrides, management of parking rules, dynamic pricing input, and other administrative settings.

Performance Evaluation Parameters:

Accuracy of Detection: Measure the precision of IoT sensors in detecting the presence and absence of vehicles. ANPR accuracy in identifying vehicles at entry/exit.

Response Time: Evaluate the time taken to update the availability status in the app after a vehicle parks or leaves. Measure the booking confirmation time after user inputs a reservation request. User Satisfaction: Assess user experience based on ease of use, availability of parking spaces, and smooth payment transactions. System Uptime and Reliability: Monitor the system's uptime, including sensor performance and app/server availability. Check for any failures in automated gates, sensors, or payments. Payment Processing Efficiency: Evaluate the speed, reliability, and security of payments made through integrated gateways (Google Pay, Net Banking). Scalability: Test how the system handles an increase in users or vehicles, especially during peak hours. Operational Cost Savings: Measure the reduction in human intervention for parking management and gate control.

Software and Hardware Setup

- Hardware Setup: IoT Sensors: Ultrasonic or infrared sensors for detecting vehicle presence in parkingspots. Cameras: CCTV with automatic number plate recognition (ANPR) for vehicle identification at entry/exit. Parking Barriers/Automatic Gates: Automated entry/exit gates controlled via RFID or ANPR systems. Central Controller/Gateway: Centralized device for collecting and processing data from all IoT sensors and cameras. Display Screens: Digital boards at the parking entrance displaying real-time avail-ability of parking spots. Smart Devices: Smartphones or tablets for user interaction via mobile apps.

- Software Setup: Parking Management System: Cloud-based or local server software for data processing, user management, and real-time updates. User Mobile App/Web Interface: App or web platform for users to view parkingavailability, make reservations, and complete payments. Admin Dashboard: Web interface for administrators to monitor parking spots, control barriers, and analyze system performance. Database: MySQL or SQL database to store sensor data, user information, reservations, and payment history. Payment Gateway Integration: Integration of third-party payment services like GooglePay, Net Banking, or others for seamless transactions.

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