Embedded Systems and Internet of Things

MINI PROJECT

Topic: - Smart Parking System

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1. Introduction

As urbanization continues to rise, the increase of automobiles escalates correspondingly. This surge in vehicle traffic inevitably exerts pressure on parking facilities, particularly in high-traffic locales such as malls and airports. Presently, the conventional manual system, typified by ticket counters at mall entrances, lacks any real-time indication of available parking spaces. This deficiency not only inconveniences the general public but also diminishes their overall experience.

The inadequacies of this traffic management system create monetary losses and increases inconveniences for those, who often resort to searching surrounding roads for available parking spots, increasing the congestion on the roads as well as leading to more accident chances due to the roads becoming narrower. This issue is particularly prominent at airports, where the urgency of catching flights amplifies the stress associated with finding suitable parking. Another area would be around malls which decreases the satisfaction and user experience with being able to find proper parking spots and navigating through congested lanes.

2. Need & Motivation

There exists an imperative need for efficient parking management solutions in urban centers to cope with escalating congestion and finite parking capacity. Conventional methods reliant on manual monitoring are not only labor-intensive but also prone to inefficiencies, resulting in monetary losses. Moreover, the frustrations endured by drivers navigating congested parking areas contribute to an overall negative experience. As society increasingly embraces automation, it is evident that the same course of action should be done for parking management.

3. Research Objective:

The primary objective of this research is to enhance the existing parking management paradigm by implementing an automated guidance system. By leveraging advancements in technology of IoT and networks to automate the process of tracking parking availability, we aim to streamline the parking experience for clients, thereby optimizing efficiency and enhancing overall satisfaction in settings such as malls and airports and other high density public areas.

4. Organization of Paper:

This paper is structured to comprehensively address the aforementioned objectives. The subsequent sections will delve into the technological framework underpinning the proposed automated parking guidance system, detailing its design, implementation, and potential benefits. Additionally, a thorough analysis of relevant literature and case studies will provide valuable insights into existing methodologies and their shortcomings. Moreover, recommendations for future research avenues will be elucidated, with a view towards continually refining and advancing automated parking management solutions.

5. Literature Review

1. IEEE Xplore - "A Smart Parking System Based on IoT and Machine Learning"

2. EV Charging Summit - "Everything You Need to Know About Wireless EV Charging"

3. MDPI Sensors - "Smart Parking Solutions Using IoT: A Comprehensive Survey"

4. ResearchGate - "IoT-based Smart Parking System"

A comprehensive review of the aforementioned research papers has been conducted to glean insights into contemporary advancements and best practices in the realm of automated parking management systems. Each paper offers unique perspectives and methodologies, contributing valuable insights to our understanding of the subject matter.

6. Methods to Investigate the Problem:

In order to investigate the challenges and opportunities inherent in the domain of automated parking management, a multifaceted approach has been adopted. Which encompasses a thorough examination of existing literature, case studies, and technological advancements pertaining to smart parking solutions. Additionally, consultations with our faculties and taking their guidance have been leveraged to gain stakeholder perspectives and identify key areas of focus.

7. Gap Areas:

The literature review has revealed several notable gap areas for further exploration, which align with the research objectives outlined earlier. These gap areas not only present opportunities for innovation but also underscore the urgency of developing robust and efficient automated parking guidance systems. Key gap areas identified include:

- **Integration of Wireless Technology:** While wireless technology holds immense potential for enhancing the scalability and flexibility of automated parking systems, there remains a lack of comprehensive frameworks and standards governing its implementation in real-world settings.
- **Machine Learning and Predictive Analytics:** The integration of machine learning algorithms and predictive analytics techniques presents a promising avenue for optimizing parking space allocation and predicting future parking demands. However, existing research in this domain primarily focuses on theoretical models rather than practical applications.
- **User Experience and Interface Design:** Despite the growing emphasis on user-centric design principles, there is a lack of research examining the impact of interface design on user satisfaction and usability. Addressing this gap is crucial for enhancing the overall user experience and promoting widespread adoption of automated parking solutions.
- **Scalability and Interoperability:** As automated parking systems will continue to increase across diverse urban landscapes, ensuring interoperability and scalability emerges as a pressing concern. However, current literature lacks comprehensive frameworks and guidelines for seamlessly integrating disparate parking systems and infrastructure components.

Additional Information:

Drawing upon insights gained from the literature review, the subsequent sections of this paper will dive deeper into these gap areas, proposing innovative solutions and methods to address existing challenges and propel the evolution of automated parking management systems. Moreover, case studies and empirical data will be analyzed to provide practical insights and validate theoretical frameworks, thereby enriching the discourse surrounding smart parking solutions.

8. Problem Description

Notions Used:

The problem at hand pertains to the inefficiencies prevalent in conventional parking management systems, hence bringing out the requirement for the development of an automated solution leveraging advanced technologies. The integration of a camera system with a Raspberry Pi serves as the main focus for this project, enabling real-time monitoring of parking occupancy and dynamic guidance of vehicles to available parking spaces through the utilization of LED lights.

Key Challenges:

- **Manual Monitoring and Guidance:** Traditional parking management systems are reliant on manual monitoring (toll booths) and self-guidance mechanisms. Hence, they are prone to inefficiencies, leading to suboptimal space utilization and prolonged search times for available parking spots.
- **Limited Real-Time Visibility:** A lack of real-time visibility into parking space availability increases congestion and frustration amongst the general public. Underscoring the need for automated systems capable of providing accurate, up-to-date information to drivers.
- 3.**Technological Integration and Compatibility:** Integrating hardware components such as cameras, Raspberry Pi, and LED lights necessitates meticulous attention to compatibility and seamless integration to ensure the efficiency and reliability of the automated parking management system.
- **Communication Protocol Selection:** The choice of communication protocol, such as MQTT, plays a pivotal role in facilitating efficient data transmission and real-time updates between devices. Ensuring the robustness and scalability of MQTT is imperative for the seamless operation of the parking guidance system.
- **User Experience Enhancement:** Enhancing user satisfaction through clear visual cues is crucial to the successful creation and effectiveness of the automated parking management system. Designing user-friendly interfaces and optimizing the functionality of LED guide lights are critical considerations in this regard.

Research Objectives:

- **Development of an Automated Parking Management System:** The primary objective is to design, develop, and implement a comprehensive automated parking management system comprising hardware components (e.g., rpi, camera, ESP8266, LEDs) and software components (e.g., image processing algorithms via OpenCV, connectivity protocols (MQTT)).
- **Integration of LED Guide Lights:** Implementing LED guide lights triggered by the automated system to direct vehicles to available parking spots. These lights will serve as clear visual indicators, simplifying the parking process and reducing search time for motorists.
- **Utilization of MQTT Protocol for Efficient Communication:** Leveraging the MQTT protocol to facilitate efficient communication between the Raspberry Pi and LED guide lights. This protocol enables real-time updates and seamless integration of data, thereby enabling dynamic adjustments in parking guidance based on changing occupancy conditions.
- **Enhancement of Parking Efficiency and User Satisfaction:** Ultimately, the overarching objective is to enhance parking efficiency, alleviate congestion, and improve user satisfaction by providing accurate, real-time parking guidance to drivers. This entails optimizing the functionality of the automated parking management system to meet the diverse needs and preferences of users while ensuring scalability and reliability in diverse parking environments.

9. Problem approach:

The Automated Parking Guiding Lights System aims to optimize parking space utilization and improve user experience by providing real-time guidance to drivers within parking lots. The system detects the presence of cars in parking spots and illuminates guiding lights to direct drivers to available spaces.

Hardware Components:

- **Raspberry Pi:** Acts as the central processing unit for image processing and communication with CCTV cameras.
- **CCTV Camera:** Provides continuous video feed of the parking lot to the Raspberry Pi (USB connected camera).
- **ESP8266:** Controls the LED light bulbs based on commands received from the Raspberry Pi via MQTT protocol.
- **LED Light Bulbs:** Installed in the parking lot to indicate available parking spaces to drivers.
- **Breadboard:** Used for connecting the LED lights to the ESP8266 for easy prototyping.

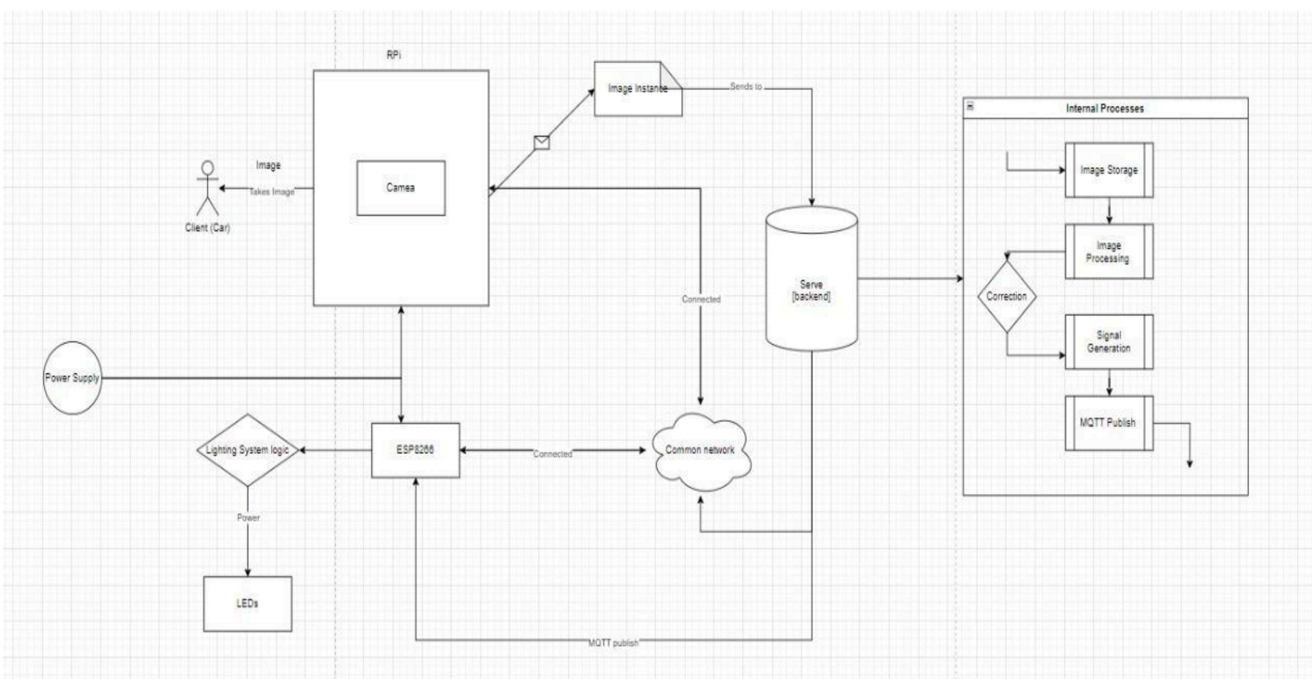
Software Components:

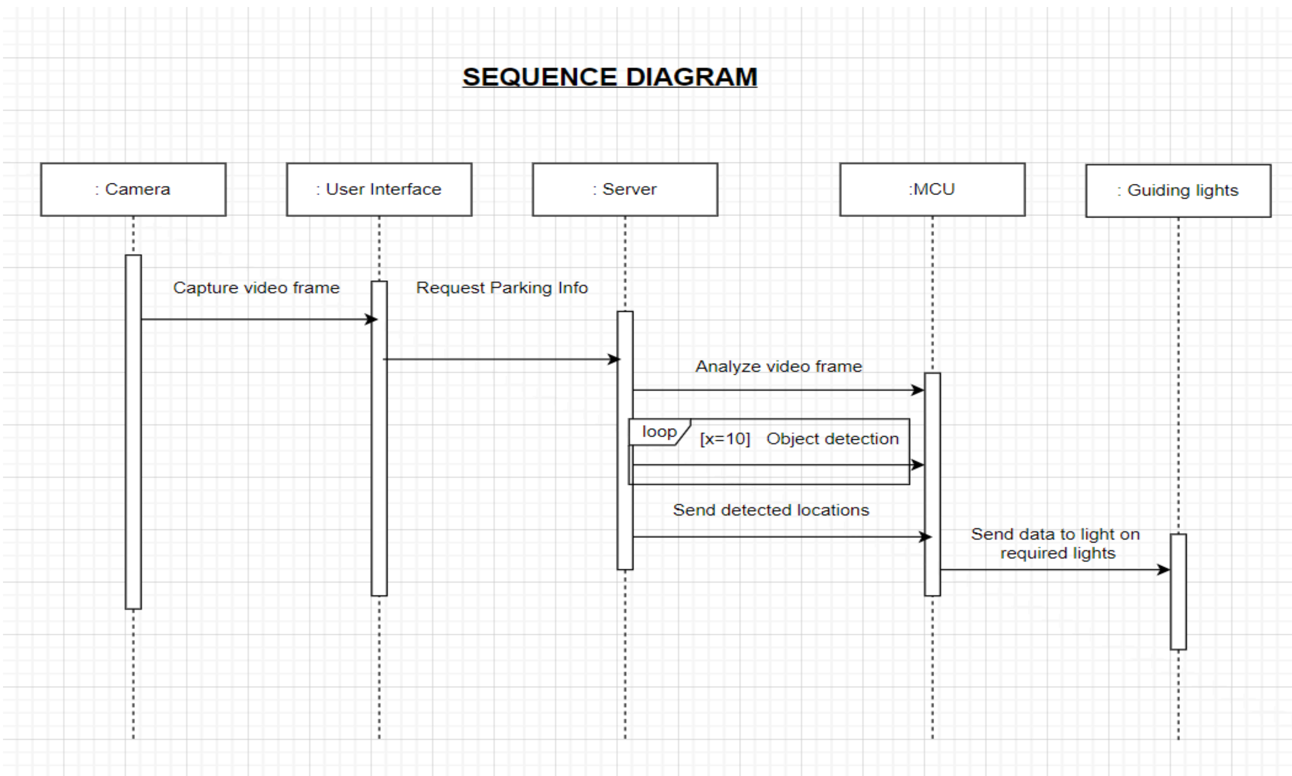
- **OpenCV in Python:** Employed for real-time object detection, specifically to identify cars within parking spots from the CCTV camera feed.
- **MQTT Protocol:** Facilitates communication between the Raspberry Pi and ESP8266 for controlling the LED lights.
- **Python Scripts:** Developed to process the video feed, detect car presence, and send commands to the ESP8266 based on the detected status of parking spots.
    - Libraries used – paho.mqtt, OpenCV, YOLO V5
    - Standard libraries – threads, os, time
- **ESP8266 Code:** Written to receive MQTT messages from the Raspberry Pi and control the LED lights accordingly.

- **Threading** - to run python code simultaneously while all processes process other packets of incoming information with a set time delay calculated via process runtime for each process frame

Prototype Operation:

- The CCTV camera continuously captures video feed of the parking lot, which is processed by the Raspberry Pi using OpenCV.
- OpenCV algorithms analyze the video frames to detect the presence of cars within parking spots in real-time.
- Once a vacant parking spot is detected, the Raspberry Pi sends commands via MQTT protocol to the ESP8266.
- The ESP8266 interprets the commands and activates the LEDs to the corresponding parking spot to illuminate.
- When a car occupies a parking spot, the Raspberry Pi updates the status and sends commands to the ESP8266 to turn off the corresponding LED light.





Product Justification:

- **Enhanced Parking Efficiency:** By providing real-time guidance to drivers, the system reduces the time spent searching for available parking spots, thus optimizing parking efficiency.
- **Improved User Experience:** The intuitive guiding lights system simplifies the parking process for users, enhancing overall satisfaction.
- **Cost-Effective Solution:** Leveraging readily available technologies such as Raspberry Pi, Arduino, and open-source software libraries like OpenCV, the system offers a cost-effective solution for parking management.
- **Scalability:** The modular design of the system allows for easy scalability to accommodate parking lots of varying sizes and configurations.

- **Integration with Existing Infrastructure:** The system can be seamlessly integrated with existing CCTV camera networks, minimizing additional infrastructure requirements.

10. Assumption:

The car should be recognized and the car count updated based on the number of cars. With an increase in the car count, the guide LED light decreases to show a reduction in parking size. The MQTT server to client protocol should work efficiently where the server sends the relay to the client on the esp32 and the LEDs should light up accordingly. Other assumptions which are crucial to the overall development are:

- Optimal Space Utilization
- Ease of Navigation
- Minimized Congestion
- Improved User Experience

11. Comparative Analysis:

Aspect	Existing Systems	Smart Parking System
Efficiency in Parking Space Utilization	Relies on manual monitoring and static signage.	Utilizes real-time monitoring and dynamic guidance.
Real-Time Parking Availability Information	Lack real-time visibility into parking availability.	Provides accurate, real-time information on parking space availability.
Technological Integration and Compatibility	Faces challenges in integrating disparate hardware components.	Seamlessly integrates hardware components using IoT technologies.

User Experience and Interface Design	Interfaces may be outdated or lack user-friendly features.	Emphasizes user-centric design principles, providing intuitive interfaces.
Scalability and Interoperability	Often lacks scalability and interoperability.	Designed with scalability and interoperability.
Cost-Effectiveness	May require significant upfront investment and ongoing maintenance costs.	Leverages cost-effective IoT technologies and open-source software.
Reliability and Maintenance	Reliability may be compromised due to manual processes.	Offers increased reliability through automated processes and real-time monitoring.
Environmental Impact	Limited environmental considerations.	Incorporates environmental sustainability features.

12. Limitations of Current studies/implementations:

- **Reliance on Proprietary Technologies:** Some smart parking solutions rely on proprietary technologies or closed ecosystems, limiting interoperability and integration with existing infrastructure and systems.
- **Limited Coverage and Incomplete Data:** Some smart parking systems may suffer from limited coverage, especially in large parking facilities or complex urban environments with multiple levels or underground parking structures. This can result in incomplete or inaccurate data, reducing the effectiveness of the system in guiding drivers to available parking spaces.
- **High Initial Investment:** The upfront cost of implementing smart parking systems, including hardware, software, and infrastructure upgrades, can be restrictive for some stakeholders, hindering widespread adoption.
- **Complex Installation and Maintenance:** The complexity of installing and maintaining smart parking systems, particularly those involving extensive sensor networks or infrastructure modifications, can pose challenges for deployment and long-term operation.
- **Limited Real-Time Accuracy:** While smart parking systems aim to provide real-time information on parking availability, accuracy and reliability issues may arise due to factors such as sensor calibration errors, stream delay, communication latency, or environmental conditions.

13. Contributions and Implications of research:

- **Technological Advancement:** The research proposes an innovative smart parking system leveraging IoT technologies, image processing algorithms, and real-time communication protocols, advancing the field of parking management.
- **Efficiency Improvement:** Implementation of the system leads to better parking space utilization, reduced congestion, and improved user experience by providing real-time guidance to drivers.
- **User Satisfaction Enhancement:** Emphasis on user-centric design principles 1and intuitive interfaces enhances satisfaction and usability, simplifying the parking process for drivers.
- **Cost-Effectiveness:** Utilization of accessible technologies makes the system cost-effective and adaptable for deployment in diverse parking environments, democratizing access to advanced parking management solutions.
- **Scalability and Interoperability:** Modular design and interoperable nature ensure scalability and seamless integration with existing infrastructure, facilitating deployment in various parking facilities.
- **Environmental Sustainability:** Real-time monitoring capabilities contribute to environmental sustainability by reducing emissions and traffic congestion, aligning with broader goals of urban sustainability.
- **Policy and Regulatory Implications:** The research informs policy decisions related to urban transportation and infrastructure development, highlighting the effectiveness of automated parking systems in addressing urban mobility challenges.

14. Conclusion:

Addressing these challenges and fulfilling the outlined objectives will not only optimize parking space utilization and streamline traffic flow but also enhance the overall user experience in parking facilities. By leveraging advanced technologies and employing a systematic approach to system design and implementation, the proposed automated parking management system has the potential to revolutionize urban parking dynamics and set a new standard for efficiency and user satisfaction

15. Future scope:

- **Enhanced Integration with Autonomous Vehicles:** As autonomous vehicles become more prevalent, there is an opportunity to integrate smart parking systems with vehicle navigation systems. This integration could allow vehicles to automatically locate and reserve parking spaces, further optimizing the parking process.
- **Predictive Analytics for Parking Demand:** Utilizing machine learning algorithms and predictive analytics, future smart parking systems could forecast parking demand based on historical data, events, and other contextual factors. This would enable proactive management of parking facilities and better allocation of resources.
- **Dynamic Pricing Strategies:** Implementing dynamic pricing strategies based on real-time demand and availability data could help optimize revenue generation for parking operators while incentivizing more efficient use of parking spaces by motorists.
- **Multi-Modal Integration:** Integrating smart parking systems with other transportation modes, such as public transit and ride-sharing services, could provide travelers with seamless end-to-end mobility solutions, reducing dependency on private vehicles and alleviating congestion.
- **Augmented Reality Navigation:** Implementing augmented reality (AR) navigation interfaces could enhance user experience by providing intuitive, real-time guidance to available parking spaces within parking facilities.

16. References:

- MQTT documentation
- RPI Documentation
- MJPG streamer documentation
- ESP8266 documentation

17. Codes:

- Camera: https://github.com/TakshDhabalia/Driving_Optimization/blob/YOLOv5/Camera.py
- Detection: https://github.com/TakshDhabalia/Driving_Optimization/blob/YOLOv5/Detection_Latest.py
- MQTT publisher: https://github.com/TakshDhabalia/Driving_Optimization/blob/YOLOv5/MQTT.py
- MQTT subscriber: https://github.com/TakshDhabalia/Driving_Optimization/blob/YOLOv5/sub_mqtt.ino