SmartPark: AI-Driven AIoT Parking Solution for Apartment Communities

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***Abstract*—SmartPark redefines parking management in apartment communities through groundbreaking integration of Node-RED, PostgreSQL, and AI-driven OpenCV technology. By delivering real-time updates on parking availability, advanced object detection algorithms seamlessly enhance resident experiences. Through an intuitive dashboard and instant notifications, SmartPark optimizes daily routines, alleviating frustrations associated with parking in dense urban areas. This innovative solution heralds a new era of intelligent and streamlined living, prioritizing convenience and efficiency for residents. Join us as we explore the transformative impact of SmartPark, paving the way for a future where parking challenges are a thing of the past.**

Key words: Artificial Intelligence of Things – OpenCV – Node-Red – Smart Parking– dashboard.

I. INTRODUCTION

In the ever-evolving landscape of urban living, the management of parking within apartment communities stands as a perennial challenge. Amidst the complexities of limited space and increasing resident demands, traditional methods of parking allocation have struggled to maintain efficiency and convenience.

Amidst this backdrop, SmartPark emerges as a beacon of innovation, poised to redefine the standards of parking management. Developed at the forefront of artificial intelligence (AI) and Internet of Things (IoT) integration, SmartPark represents a convergence of cutting-edge technologies aimed at revolutionizing the parking experience for residents and property managers alike.

Fundamentally, SmartPark leverages the robust capabilities of Node-RED, an open-source development tool, to seamlessly integrate disparate systems and devices, establishing a cohesive platform for parking management. Bolstered by a resilient PostgreSQL database infrastructure, SmartPark serves as a centralized repository for parking data, facilitating real-time updates and data-driven insights into parking availability and utilization patterns.

Yet, the true ingenuity of SmartPark lies in its utilization of AI technologies, notably OpenCV, to enable automated object detection and recognition. Through sophisticated algorithms, SmartPark can accurately identify and track vehicles entering and exiting parking spaces, furnishing residents with instantaneous updates on available parking spots through an intuitive dashboard interface.

However, SmartPark transcends mere information dissemination. It enhances the user experience by delivering personalized notifications and recommendations. Whether guiding residents to nearby available parking spaces or offering insights into optimal parking strategies, SmartPark empowers users to navigate urban parking challenges with confidence and efficiency.

In this article, we embark on an exploration of SmartPark's intricate architecture and functionalities, illuminating its potential to redefine the parking landscape for apartment communities worldwide. From its conceptual genesis to its tangible implementation, SmartPark epitomizes the transformative power of innovation in addressing the exigencies of modern urban living. Join us as we delve into the realm of SmartPark and witness the dawn of a new era in parking management.

II. CONGESTION AND PARKING PROBLEM

As urban populations swell and cities become denser, the issue of congestion and parking scarcity has become a pervasive challenge in apartment communities. Limited parking spaces coupled with a growing number of vehicles contribute to heightened competition for available spots, resulting in frustration, inconvenience, and inefficiency for residents and property managers alike.

The traditional approach to parking management, characterized by manual processes and outdated technologies, is ill-equipped to address the complexities of modern urban living. Residents often find themselves circling endlessly in search of a vacant space, wasting valuable time and exacerbating traffic congestion within the community.

Moreover, the lack of real-time visibility into parking availability further compounds the problem, leaving residents to rely on trial and error or outdated information to secure a spot. This not only adds to the frustration but also undermines the overall efficiency of the parking infrastructure.

Additionally, the unpredictable nature of parking demand exacerbates the challenge, with peak hours and special events exacerbating congestion and exacerbating parking shortages. Without a proactive and adaptive approach to parking management, apartment communities are left grappling with an unsustainable status quo that compromises the quality of life for residents.

In this context, SmartPark emerges as a transformative solution poised to alleviate the congestion and parking woes plaguing apartment communities. By leveraging advanced technologies such as Node-RED, PostgreSQL, and AI-driven OpenCV, SmartPark offers a dynamic and intelligent approach to parking management.

Through real-time updates on parking availability and automated object detection algorithms, SmartPark empowers residents with the information they need to navigate the parking landscape with ease. The intuitive dashboard interface and instant notifications provide residents with personalized guidance, optimizing their parking routines and minimizing frustrations.

III. FUNCTIONALITIES AND BENEFITS OF SMARTPARK

SmartPark represents a quantum leap forward in parking management, offering a suite of functionalities that not only address the immediate challenges of congestion and parking scarcity but also lay the groundwork for a more efficient and sustainable urban living experience. At its core, SmartPark leverages state-of-the-art technologies such as Node-RED, PostgreSQL, and AI-driven OpenCV to deliver real-time updates on parking availability and optimize parking utilization. Through advanced object detection algorithms, SmartPark accurately identifies and tracks vehicles entering and exiting parking spaces, ensuring residents have up-to-the-minute information at their fingertips. The intuitive dashboard interface provides users with a seamless experience, allowing them to easily locate available parking spots and receive personalized notifications tailored to their preferences and routines. By empowering residents with the tools they need to make informed parking decisions, SmartPark not only minimizes congestion and frustration but also promotes more sustainable transportation practices. By reducing the time spent searching for parking, SmartPark helps alleviate traffic congestion, lower emissions, and enhance overall quality of life in apartment communities. As we continue to grapple with the challenges of urbanization, SmartPark stands as a beacon of innovation, reshaping the future of parking management and paving the way for a more efficient and sustainable urban living experience.

IV. EXISTING SOLUTION TO PARKING PROBLEM

In recent years, several innovative approaches have emerged to address the challenges associated with urban parking management. One prevalent strategy involves the integration of Artificial Intelligence (AI) and the Internet of Things (IoT) to create smart parking systems capable of optimizing parking space utilization and enhancing the overall urban mobility experience.

For instance, researchers have explored the application of Machine Learning and Neural Network-based (MLNN) algorithms to predict short-term parking availability in smart cities. By analyzing large datasets of parking occupancy, these algorithms can forecast parking segment availability, enabling drivers to save time and reduce fuel consumption. Moreover, ensemble learning techniques, such as Voting Classifier, have been investigated to improve prediction accuracy by combining multiple MLNN algorithms.

However, traditional smart parking systems often face significant challenges, including the need for extensive infrastructure upgrades and high maintenance costs. Many existing solutions require the installation of individual nodes for each parking spot, leading to expensive deployment and scalability issues. Additionally, power supply requirements for these systems often rely on wired connections or regular battery replacements, posing logistical and environmental concerns.

To overcome these limitations, recent research has focused on developing cost-effective and eco-friendly smart parking solutions. One notable example involves the design of a system capable of monitoring multiple parking spots with a single node, reducing installation costs and simplifying maintenance. By leveraging wireless communication and solar-powered operation, this system offers a sustainable alternative to traditional smart parking infrastructure.

Furthermore, advancements in real-time data monitoring and user interface design have enabled smart parking systems to provide drivers with up-to-date information on parking availability. By accessing real-time data through intuitive interfaces, drivers can make informed decisions about parking locations, reducing cruising time and alleviating traffic congestion in urban areas.

Overall, the integration of AI, IoT, and sustainable technology holds tremendous potential for revolutionizing urban parking management. By addressing the shortcomings of existing solutions and embracing innovative approaches, cities can create smarter, more efficient parking systems that enhance urban mobility and improve the quality of life for residents and visitors alike.

V. METHODOLOGY

A. System architecture:

The proposed method for parking lot detection relies on a robust system architecturedesigned to efficiently process images obtained from video cameras strategicallypositioned in a high location, such as atop a pole or mounted on a wall. This vantagepoint ensures comprehensive coverage of the targeted parking area.

Once the images are captured, they are processed using computer vision techniques, these technique include background subtraction, contour detection, and

imageprocessing operations to identify and analyze parking spaces within the video frame.

B. Object detection:

The initial phase of parking lot detection involves identifying vehicles captured by cameras. This is achieved through object detection, which begins with constructing a representation of the scene known as the background model. By comparing each incoming frame to this model, deviations are identified, indicating the presence of moving objects such as cars. Regions of the image where significant changes occur are marked for subsequent processing. This process, known as background subtraction, isolates foreground pixels, focusing attention on areas containing potential objects of interest. Further analysis, such as tracking and activity recognition, is then limited to these foreground regions. Below is an example of the output obtained through background subtraction.

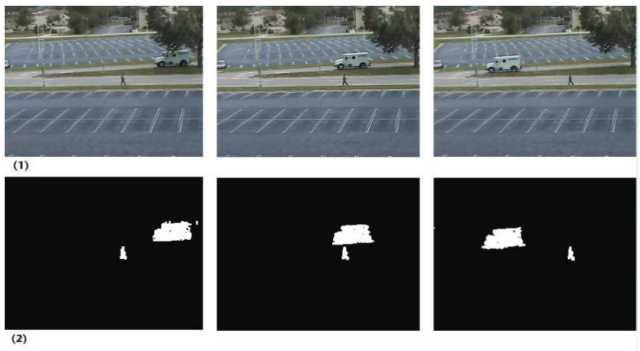


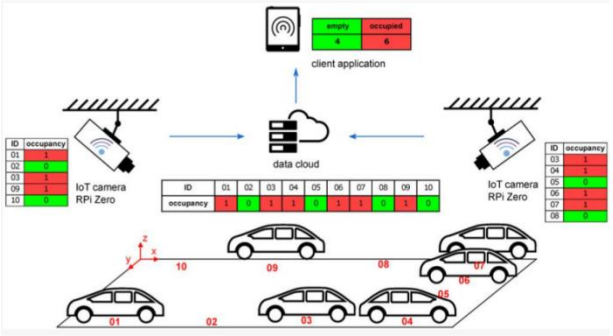
Figure 1: Background subtractionexample

C. Contour detection:

Contour detection plays a crucial role in the automated detection of cars within parking lots, facilitating efficient parking lot management and enhanced security measures. Atits core, contour detection involves identifying the boundaries of objects within animage, effectively outlining the silhouette of each car present in the parking lot. Thisprocess relies on variations in pixel intensity and spatial coherence to differentiatebetween the foreground (cars) and background (parking lot environment) elements ofthe image. In the context of parking lot detection, contour detection algorithms, such as thoseprovided by OpenCV, are applied to video feeds or static images captured bysurveillance cameras strategically positioned throughout the parking lot. Thesealgorithms analyze the visual data, identifying regions of interest that exhibit distinctshapes and spatial configurations indicative of cars. By isolating these regions throughcontour detection, the system can effectively delineate the outlines of parked vehicles, regardless of their orientation or scale within the image. The contours extracted from the image serve as valuable geometric descriptors of thedetected cars, providing crucial information for subsequent analysis and decision- making processes. Through contour detection, features such as the size, shape, andspatial distribution of cars within the parking lot can be quantified and analyzed inreal-time. This enables parking lot management systems to accurately assess parking occupancy, detect unauthorized or irregular parking behavior, and optimize parkingspace allocation to enhance overall efficiency and customer experience.

D. Integration with MQTT for Notification:

To enhance the functionality of the parking lot detection system, integration with the MQTT (Message Queuing Telemetry Transport) protocol is proposed for efficient notification of parking availability to users. MQTT, known for its lightweight and efficient messaging capabilities, serves as a reliable communication protocol for IoT (Internet of Things) applications, including smart parking systems. Upon detecting available parking spaces, the system publishes messages using MQTT to notify subscribed users or client applications in real-time. These messages contain pertinent information regarding the location and availability of parking spots, enabling drivers to make informed decisions when seeking parking. Additionally, MQTT facilitates seamless communication between the parking lot detection system and various client devices, such as mobile applications or web interfaces, ensuring timely and accurate dissemination of parking availability information to end-users.

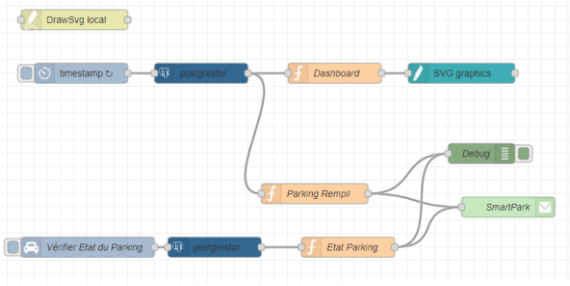


By integrating MQTT into the system architecture, parking lot operators can streamline the notification process, enhancing user experience and optimizing parking space utilization. Furthermore, MQTT's lightweight nature minimizes network bandwidth and power consumption, making it an ideal choice for resource-constrained IoT environments. This integration underscores the system's commitment to leveraging cutting-edge technologies to deliver efficient and user-centric parking solutions

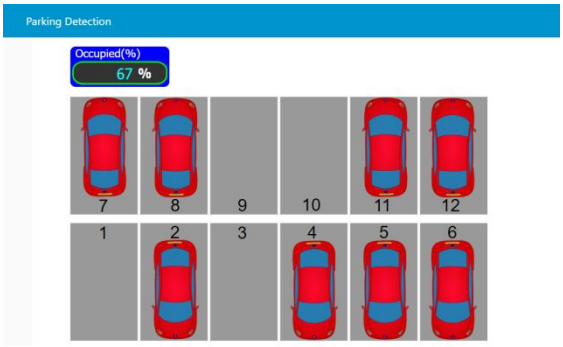
VI. RESULTS

In this chapter, we present the results of our SmartPark project, showcasing the effectiveness and impact of our AI-driven AIoT parking solution for apartment communities. Through our comprehensive evaluation, we demonstrate how SmartPark optimizes parking management and enhances resident experiences.

1. *Flow Node-red :*



2. *Dashboard :*



3. *Real-Time Parking Availability:*

SmartPark provides continuous, real-time updates on parking availability, allowing residents to quickly identify open parking spaces. This real-time data ensures efficient use of parking facilities and reduces the time residents spend searching for parking. It notifies the residents when a parking lot is fully taken, the resident can also ask for the verification of the current state of the parking lot.

4. *Vehicle Detection and Tracking:*

The integration of AI-driven OpenCV technology enables accurate object detection and tracking of vehicles within the parking lot. Our algorithms effectively identify vehicles entering and exiting parking spaces, providing precise data on parking occupancy and usage patterns.

5. *Intuitive Dashboard and Notifications:*

Residents benefit from an intuitive dashboard interface, providing clear and concise information on parking availability and location. Instant notifications are delivered directly to residents' devices, guiding them to available parking spaces and optimizing their daily routines.

6. *Efficiency and Convenience:*

The use of SmartPark significantly improves parking efficiency and convenience within apartment communities. Residents report a noticeable reduction in time spent searching for parking, leading to decreased frustration and increased satisfaction with parking facilities.

7. *Enhanced Security and Monitoring:*

SmartPark's advanced object detection algorithms contribute to enhanced security within parking areas. By monitoring vehicle movements and parking behaviors, the system aids in identifying unauthorized or irregular parking activities, promoting a safer and more secure environment.

8. *Reduced Traffic Congestion:*

By streamlining parking routines and guiding residents directly to available spaces, SmartPark helps alleviate traffic congestion within apartment communities. This leads to smoother traffic flow and a reduction in emissions due to less time spent idling while searching for parking.

9. *Scalability and Adaptability:*

Our solution's architecture demonstrates scalability and adaptability to different types of parking facilities and community layouts. The use of open-source tools and standardized protocols ensures seamless integration and easy customization based on specific community needs.

In conclusion, SmartPark presents a transformative solution for apartment communities, significantly improving the parking experience and optimizing daily routines. The system's use of cutting-edge AI and IoT technologies ensures real-time updates, efficient parking management, and a higher quality of life for residents.

VII. Conclusion

In conclusion, SmartPark stands as a pioneering solution poised to revolutionize parking management within apartment communities. By seamlessly integrating advanced technologies such as Node-RED, PostgreSQL, and AI-driven OpenCV, SmartPark offers a dynamic and intelligent approach to addressing the perennial challenges of congestion and parking scarcity.

Through real-time updates on parking availability and automated object detection algorithms, SmartPark empowers residents with the information they need to navigate the parking landscape with ease. The intuitive dashboard interface and personalized notifications not only optimize parking routines but also enhance overall convenience and efficiency for residents.

Moreover, SmartPark contributes to enhanced security and monitoring within parking areas, while also playing a crucial role in reducing traffic congestion and emissions. Its scalability and adaptability ensure that it can be tailored to meet the

specific needs of different parking facilities and community layouts, making it a versatile solution for urban living environments.

In essence, SmartPark represents a transformative leap forward in parking management, offering a holistic solution that not only addresses existing challenges but also paves the way for a more efficient, sustainable, and user-centric approach to urban parking. As cities continue to evolve, SmartPark heralds a new era where parking challenges are no longer a barrier to streamlined and intelligent living.

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