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Enhancing Urban Mobility: AI-Driven Smart Intelligent Parking Systems for Smart Cities

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Abstract:
Urbanization and increased vehicle growth pose significant challenges to parking management. making it an important component of smart city infrastructure. traditional parking system It relies on manual supervision or basic sensor technology. It cannot solve problems such as congestion and wastage of fuel. and environmental degradation effectively This paper presents an advanced smart parking system (SIPS) that leverages artificial intelligence (AI), internet of things (IoT), and machine learning for a transformational solution. The proposed system combines real-time dice collection through IoT-based sensors, predictive analysis using machine learning algorithms. and an automatic navigation system for parking lots via a mobile app. Computer vision powered by IA guarantees accurate detection of parking availability. while computation also supports stepwise data processing and continuous communication between stakeholders. The system's innovative features include dynamic allocation of parking waves. Predictive demand management and an improved user experience through real-time updates. Navigation helps and digital payment options Benefits range from reduced search times. Reduce fuel use and reduce carbon emissions to a minimum Promote sustainability and efficient traffic flow. This is despite challenges such as operational costs and data privacy. Integrating emerging technologies such as blockchain, edge computing and automatic vehicles Promising improvements in scalability, accuracy, and safety, the SIPS model exemplifies the potential of technology-based solutions to create more sustainable urban ecosystems. Future research directions involve addressing existing limitations and integrating SIPS into the broader smart city structure. To improve urban mobility and the environment.

Keywords: Automation; Machine Learning; Intelligent Smart Parking; Artificial Intelligence.

1. Introduction

The concept of smart cities has emerged as a solution to the challenges posed by rapid urbanization, population growth, and increasing vehicle ownership [1][2]. Parking management is one of the critical components of smart city infrastructure, as inefficient parking solutions lead to congestion, fuel wastage, and environmental pollution. According to the World Economic Forum, drivers spend an average of 20 minutes searching for parking in urban areas, contributing significantly to traffic issues and greenhouse gas emissions. Traditional parking systems, such as manual and sensor-based systems, lack scalability and are unable to meet the dynamic demands of modern cities [3][5]. Artificial Intelligence (AI), in combination with IoT and machine learning, offers a promising solution to enhance parking systems by providing real-time monitoring, predictive analytics, and user-friendly interfaces for vehicle navigation [4][6][7]. Figure.1 represent the Visual representation of a smart intelligent parking system in a futuristic smart city. This paper presents an enhanced smart intelligent parking system that uses AI for efficient parking space detection, predictive analysis, and optimal route recommendations [8].

In the figure 1 shows the enhanced smart intelligent parking system combines computer vision, machine learning, IoT, and cloud-based technologies to deliver a scalable and efficient solution for smart cities. By leveraging emerging technologies such as edge computing, blockchain, and autonomous vehicles, future research can further enhance the capabilities of intelligent parking systems and contribute to sustainable urban development [9].

Figure 1. Smart intelligent parking system in a futuristic smart city.

1.1. Smart intelligent Parking System with various Components

The rise of smart cities and the proliferation of vehicles in urban areas have created the need for Intelligent Parking Systems (IPS) [35]. These systems leverage cutting-edge technologies to address challenges such as parking congestion, inefficient use of parking space, and pollution caused by prolonged parking searches. The image, titled "Parking 4.0," highlights six critical components that form the foundation of a modern intelligent parking system [36][38].

Figure 2. Components of smart parking system

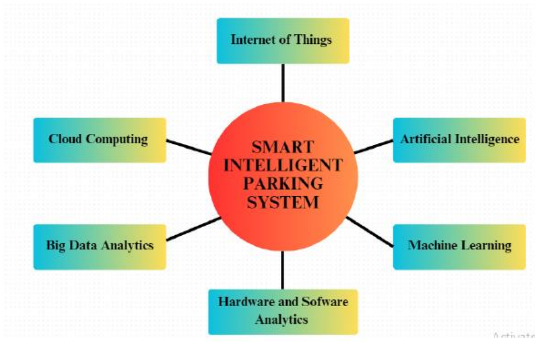

Figure 3. Components of smart parking system

The Figure 2 proposed intelligent parking system comprises several advanced components that work together to create an efficient and automated solution for modern urban environments. The Internet of Things (IoT) is a crucial element that facilitates real-time monitoring and data collection in parking systems. IoT technology uses smart sensors such as ultrasonic, RFID, or magnetic sensors embedded in parking spaces to detect vehicle presence [40][41][42]. This information is transmitted through wireless communication protocols like Zigbee, LoRa, or NB-IoT to a central system, ensuring continuous communication between hardware (parking slots) and software (user applications). The benefits of IoT in parking systems include providing real-time availability of parking slots, reducing drivers' search times, and enhancing resource efficiency and data accuracy. Figure 3 shows another critical component is Artificial Intelligence (AI), which serves as the brain of the parking system. AI enables smart decision-making, predictive analysis, and automated parking optimization. AI-based computer vision techniques, such as object detection models like YOLO, are used to identify vacant slots through camera feeds, while historical and real-time data enable predictive parking. Additionally, AI provides automated parking assistance for drivers, optimizing parking space utilization, improving detection accuracy under dynamic conditions, and reducing manual intervention in parking management [43]. Machine Learning (ML) complements AI by analysing historical parking data to predict parking trends and demand. Machine learning algorithms, including regression models, Random Forest, and neural networks, forecast parking availability at specific times and analyse vehicle traffic patterns to optimize slot assignments. These capabilities minimize congestion, predict peak demand, and provide real-time parking recommendations, which collectively reduce driver wait times and enhance operational efficiency. The backbone of the intelligent parking system is Cloud Computing, which ensures the storage, processing, and analysis of vast amounts of data generated by IoT and AI technologies [44]. Cloud platforms enable real-time data storage and retrieval, support analytics and reporting, and integrate seamlessly with user-facing mobile and web applications. This component ensures scalability for large-scale systems, reduces the need for local storage, and enhances data accessibility for end users and city administrators. Another essential aspect is the combination of Hardware and Software Analytics, where physical devices like cameras, sensors, and actuators work alongside data analytics tools to provide accurate and actionable insights. Cameras and sensors detect vehicle presence and monitor parking operations, while software tools analyze and visualize the data [45]. This integration delivers real-time insights, facilitates connection with broader smart city infrastructure, and reduces system downtime, ensuring reliable parking operations. The concept of smart intelligent parking system Integration ties all these technologies—IoT, AI, Machine Learning, Cloud Computing, and Hardware/Software Systems—into a unified solution. Parking 4.0 represents a fully automated and connected parking management system that provides real-time slot availability updates through mobile applications, predictive analytics for managing parking demand, and automatic navigation for drivers to available spaces. The intelligent parking system, as depicted in the Figure 3, which comprises six interconnected components: IoT, Artificial Intelligence, Machine Learning, Cloud Computing, Hardware & Software Analytics, and smart intelligent parking system. Together, these components create a comprehensive parking management solution capable of reducing traffic congestion, enhancing user convenience, and optimizing resource allocation in smart cities [46][48].

1.2. Parking Management System

A Parking Management System is a comprehensive solution designed to streamline and optimize the operation of parking facilities. It integrates technology such as automated entry and exit systems, ticketing, payment processing, and real-time occupancy monitoring to enhance efficiency and user convenience. These systems often use IoT devices, sensors, and software platforms to manage parking spaces effectively, reduce congestion, and improve resource utilization. They cater to diverse settings, including commercial complexes, residential areas, airports, and public parking lots. By minimizing manual intervention, a Parking Management System ensures seamless traffic flow, enhances security, and provides data analytics for better decision-making and revenue management. [49][50]

1.2.1. Parking Allocation Problem

The core problem lies in the inefficiency and ineffectiveness of traditional parking systems in managing parking spaces. Figure 4 shows the car parking allocation system in smart city. The lack of real-time information about parking availability leads to time wastage, traffic congestion, and environmental degradation. Drivers often spend excessive amounts of time searching for vacant parking spaces, which increases fuel consumption and vehicle emissions, further exacerbating environmental issues. Figure. 5 shows the real picture of parking allocation area in smart city [51]. A Smart Parking Intelligent System is needed to:

1. Provide real-time updates on parking slot availability using automated sensors and data analytics.

2. Optimize the utilization of parking spaces to reduce congestion and improve operational efficiency.

3. Guide drivers efficiently to vacant parking slots, minimizing the time spent searching for parking.

4. Address the environmental impact of idling vehicles by reducing fuel wastage and emissions.

5. Enhance the user experience by providing seamless parking navigation, reservation options, and automated payment mechanisms.

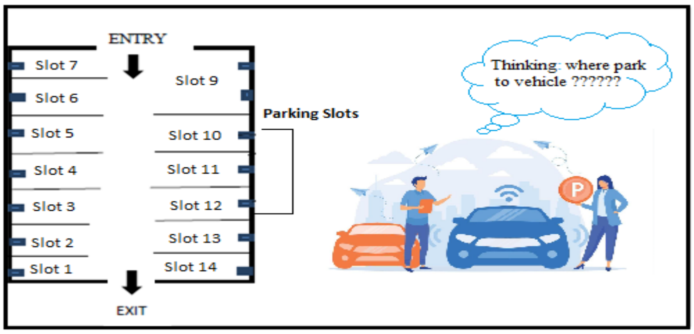

Figure 4. Car parking allocation in smart parking intelligent system

The primary objective is to develop a system that effectively integrates technology with parking management to create a smarter, greener, and more efficient urban parking ecosystem. As cities evolve and populations increase, the demand for parking spaces has outpaced the supply. Conventional parking systems are no longer capable of meeting this growing demand efficiently.

Figure 5 (a) and 5(b). Real picture of smart parking intelligent system

The following issues characterize the current state of parking systems:

- Manual Parking Management: Traditional parking lots rely on human supervision to monitor occupancy and availability. This approach is error-prone, labour-intensive, and inefficient.

- Inefficient Space Utilization: Drivers often fail to locate vacant parking spaces due to the lack of proper indicators or real-time information. As a result, parking spaces remain underutilized.

- Time Wastage: Drivers spend significant time searching for parking spaces, particularly in high-traffic urban areas. Studies have shown that up to 30% of urban traffic congestion is caused by vehicles looking for parking.

- Environmental Impact: Increased fuel consumption caused by vehicles idling and circling parking lots contributes to higher carbon emissions, exacerbating urban air pollution.

- Economic Loss: Businesses and municipalities suffer financial losses due to poor parking infrastructure and inefficient management, which result in uncollected fees and reduced operational efficiency.
- User Frustration: Drivers experience frustration and stress due to the unavailability of parking spaces, lack of navigation support, and unclear occupancy indicators.

1.3. Research Problem

A Smart Parking Intelligent System addresses the growing challenges of urban mobility, such as traffic congestion, inefficient parking space utilization, and increased environmental impact caused by vehicles searching for parking. Traditional parking systems often lack real-time information and automation, leading to unnecessary delays, fuel consumption, and frustration for drivers. The problem is further exacerbated in densely populated cities, where limited parking spaces must accommodate a rapidly increasing number of vehicles. This inefficiency not only impacts individual drivers but also contributes to broader issues, including air pollution and economic losses due to wasted time and resources. The Smart Parking Intelligent System aims to optimize parking management by integrating technologies such as sensors, IoT, and data analytics to provide real-time parking availability updates, automated space allocation, and seamless payment options, ultimately creating a more efficient, sustainable, and user-friendly parking experience. The following Figure 6 shows a parking lot where some spaces are marked occupied (indicated with an "X" means wrong parking) and real-time parking availability is denoted using sensors with red and green indicators. A vehicle (red car) is searching for a vacant spot.

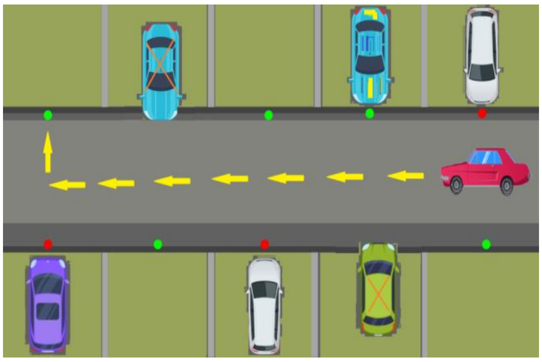

Figure 6. Inefficient car parking lot system

1.4. Benefits of the Smart Parking Intelligent System

The Smart Parking Intelligent System offers a wide range of benefits that enhance urban mobility, sustainability, and convenience, making it a vital component of modern smart cities. By leveraging technologies like IoT, Artificial Intelligence, Machine Learning, and Cloud Computing, smart parking systems provide real-time parking space availability, significantly reducing the time drivers spend searching for vacant spots. This, in turn, minimizes fuel consumption and lowers carbon emissions, contributing to a cleaner and greener environment [52]. The system optimizes parking space utilization, ensuring that every available slot is efficiently managed, which helps alleviate traffic congestion in busy urban areas. Predictive analytics powered by AI and machine learning allow for better demand forecasting, enabling city administrators to manage peak-hour parking effectively. Furthermore, smart parking systems offer enhanced user convenience through mobile applications that provide live updates, directions to available spots, and cashless payment options, ensuring a seamless experience. Businesses and governments benefit from improved revenue generation through automated payment systems, dynamic pricing, and better enforcement of parking regulations. Additionally, the integration of hardware, such as sensors and cameras, with advanced software analytics ensures higher accuracy and reliability in detecting vehicle presence, which reduces errors and manual intervention. Overall, smart parking systems improve urban infrastructure efficiency, reduce stress for drivers, and promote sustainable urban development, making cities smarter, safer, and more liveable [8],[22],[23].

1.5. Objectives of this research

The objective of this research will be to collect, study and suggest different challenges and opportunities while building a smart city in India. The research will be done on existing top sustainable smart cities and provide a road-map to build one in India. Getting to that position is hard, considering India's population, slums, literacy rate, living standard, people awareness, corruption, and economy; but it is not impossible as India already has a metropolitan city model and technical richness. Additionally, an impact factor can be formulated and calculated after analysing the data, collected from existing sustainable smart cities from other parts of the world. To summarize, the research will be done to make sustainable smart cities in India, keeping these objectives in mind:

I. Gather information on all the existing components of the world's top 10 sustainable smart cities, and then compare them with the proposed components envisioned for smart cities in India. Once such list is available, sort out the feasible components which can be implemented in selected smart cities of India.

II. Perform research on the technical challenges in implementing above found components, to make sustainable smart cities in India.

2. Literature Review

The rise of smart cities has intensified the need for innovative solutions to urban challenges, particularly parking management [10]. A significant point of research has focused on intelligent parking systems to address inefficiencies in traditional parking solutions. This part critically reviews existing parking systems, the application of artificial intelligence in parking management, and the challenges that persist in current systems, leading to the need for an enhanced AI-based parking system [11][12][13]. Traditional parking systems primarily rely on manual monitoring, ticket-based solutions, and basic sensor systems. Manual systems require human intervention, leading to errors and time delays [14][15][16]. Moreover, traditional parking solutions cannot meet the dynamic parking needs of smart cities where urban mobility plays a pivotal role in sustainability [17]. In this paper proposed manual systems contribute to unnecessary fuel consumption and increase urban pollution as drivers search for vacant slots. Sensor-based parking systems emerged as an alternative to manual methods. These systems use ultrasonic, infrared, or magnetic sensors to detect the presence of vehicles in parking slots. IoT-enabled sensors allow real-time monitoring and data collection to indicate parking slot occupancy [18] Smith et al. (2022), In this paper the highlights that sensor-based parking systems significantly improve efficiency by providing drivers with accurate data on parking availability. However, these systems have limitations in terms of scalability, installation costs, and maintenance requirements. For instance, deploying sensors over large parking areas is expensive and prone to wear and tear, particularly in adverse weather conditions. Artificial Intelligence (AI) has revolutionized smart parking systems by addressing the shortcomings of traditional and sensor-based systems. AI-driven systems leverage computer vision and machine learning algorithms to monitor, analyse, and predict parking slot availability. Computer vision models, such as Convolutional Neural Networks (CNNs), are trained to detect and classify parking spaces using camera feeds [19]. Zhang et al. (2020), In this research author introduced the YOLO (You Only Look Once) algorithm, which has become a benchmark in real-time object detection. YOLO models are particularly effective for parking systems because they offer high accuracy and rapid detection speeds [20], Redmon and Farhadi (2018), Authors demonstrated the effectiveness of YOLOv4 in parking space detection, achieving accuracy rates above

90% in real-world parking environments. Machine learning algorithms play a critical role in enhancing parking systems by enabling predictive analytics. Predictive analytics uses historical data to forecast parking availability at specific locations and times [21]. Li et al. (2023). In this paper authors highlight the application of Random Forest and Linear Regression models to predict parking slot occupancy patterns based on factors such as time of day, weather conditions, and vehicle density. Predictive parking systems reduce driver wait times, optimize space utilization, and contribute to efficient traffic flow. The integration of IoT with AI further enhances parking management systems. IoT sensors provide real-time data on parking occupancy, which is processed and analysed using AI algorithms. This combination ensures accurate and dynamic parking updates [22]. Singh et al. (2021), In this author demonstrated that IoT-enabled smart parking systems reduce vehicle idle times by 30%, thereby contributing to lower fuel consumption and reduced carbon emissions. Cloud-based platforms play a significant role in this integration by ensuring seamless communication between IoT sensors, AI algorithms, and user interfaces. Despite the advancements in AI-based parking systems, several challenges persist. One of the primary challenges is the high cost of deploying hardware such as cameras and IoT sensors. In large urban areas, the scalability of these systems becomes a concern due to infrastructure and financial constraints [23]. Research conducted by Huang et al. (2022). Furthermore, the processing and storage of vast amounts of real-time data require robust cloud infrastructure, which adds to the overall implementation cost. Another challenge is data privacy and security. AI-driven parking systems collect sensitive user data, such as vehicle location and personal payment information, raising concerns about cyber security and data breaches. Authors ensuring data privacy in AI systems is critical for widespread adoption in smart cities. Additionally, the accuracy of AI algorithms in detecting parking slots can be affected by external factors such as poor lighting conditions, occlusions, and weather variations. Computer vision models, while accurate under ideal conditions, may struggle with real-time detection in low-visibility environments [24]. According to Zhang and Lee (2021), Researchers suggests that advanced deep learning models, such as Faster R-CNN and Mask R-CNN, can improve the robustness of parking detection systems by enhancing object localization and segmentation. Edge computing enables data processing at the device level, reducing latency and dependence on cloud infrastructure. This approach enhances the efficiency and scalability of smart parking systems, particularly in large urban environments. Blockchain technology, on the other hand, offers secure and decentralized data storage, addressing concerns related to data privacy and cybersecurity [25]. Kim et al. (2022), in this paper authors highlight the potential of blockchain-integrated AI systems for secure, real-time parking management. Another innovative solution involves the use of autonomous vehicles (AVs) in smart parking systems. Autonomous vehicles can communicate with AI-powered parking systems to identify vacant slots and park without human intervention studies by Kumar et al. (2023). This paper emphasizes the role of AVs in improving parking efficiency and reducing traffic congestion.[26] AV-enabled smart parking systems eliminate the need for driver intervention, further optimizing space utilization and reducing fuel consumption. The literature also emphasizes the importance of user-friendly interfaces in smart parking systems. Mobile applications integrated with AI-driven parking solutions provide end users with real-time updates, navigation assistance, and payment options. These applications improve user experience and ensure the widespread adoption of smart parking systems [27]. Wang et al. (2023), This paper proposed a mobile application combined with AI and IoT can reduce parking search times by 40%, contributing to enhanced urban mobility. While significant progress has been made in developing AI-based parking systems, there is still a need for further research to enhance the accuracy, scalability, and affordability of these solutions [28] According to Smith et al. (2022). Future developments in deep learning, edge computing, and blockchain technology hold promise for addressing existing limitations and improving system performance. Moreover, the integration of AI-powered parking systems with smart city infrastructure, such as traffic management and energy-efficient systems, will play a crucial role in building sustainable urban environments. Table 1 shows the evolution and comparative analysis of traditional, sensor-based, AI-driven, and hybrid parking systems in addressing urban parking challenges [29][30][31][32][34].

Table 1. Summarizing the literature review in some key points

Feature	Traditional Parking Systems	Sensor-Based Parking Systems	AI-Driven Parking Systems	Hybrid Parking Systems (Future Direction)
Key Technology	Manual monitoring, ticket-based systems	Ultrasonic, infrared, or magnetic sensors, IoT	Computer vision, machine learning, IoT, cloud computing	AI, IoT, edge computing, blockchain, autonomous vehicles
Efficiency	Low	Moderate	High	Very high
Scalability	Limited	Limited due to high deployment costs	Better than traditional and sensor-based systems	High, enabled by edge computing and blockchain
Cost	Low to moderate	High (installation and maintenance costs)	High (hardware and cloud infrastructure costs)	Moderate (optimized by edge computing and decentralized tech)
Environmental Impact	High (fuel consumption and pollution from searching)	Reduced idle times but still dependent on sensor health	Reduced emissions with optimized traffic flow and predictions	Further reduced with AV integration and real-time optimizations
User Experience	Poor (time delays, manual errors)	Improved with real-time availability data	Excellent (real-time updates, navigation, automated payments)	Excellent, with seamless AV integration and enhanced security
Accuracy	Low (prone to human error)	High under ideal conditions, limited by sensor failures	Very high, dependent on lighting and environmental conditions	Very high, leveraging advanced deep learning models
Challenges	Labor-intensive, time delays	Scalability, maintenance, and wear and tear issues	Cost, data privacy, real-time processing under poor conditions	Infrastructure costs, user adoption, data interoperability
Integration Potential	Minimal	Limited (basic IoT integrations)	Extensive (mobile apps, smart city systems)	Extensive, with seamless integration across smart city platforms
Emerging Enhancements	-	-	Advanced AI models (e.g., YOLO, Faster R-	Blockchain for privacy, AVs for efficiency, edge

			CNN, Mask R-CNN)	computing for scalability

The literature highlights the potential of AI-driven parking systems in addressing the challenges of urban parking management. Traditional and sensor-based systems have proven inadequate to meet the demands of smart cities, while AI-powered solutions offer significant improvements in efficiency, accuracy, and user experience. However, challenges such as hardware costs, data privacy concerns, and environmental factors must be addressed to ensure the successful implementation of these systems.[37][38]

3. **Research Methods**

The proposed Smart Parking Intelligent System aims to address urban parking challenges by integrating advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), and Cloud Computing into a unified solution. The system illustrated in Figure. employs IoT-enabled sensors and cameras installed in parking spaces to detect vehicle occupancy in real time and transmit data to a centralized cloud-based platform. AI and ML algorithms analyse this data to identify patterns, predict parking availability, and optimize parking slot utilization based on demand [53]. The solution includes a mobile application that provides users with real-time updates on available parking spaces, navigation assistance to the nearest vacant spot, and seamless digital payment options. Additionally, predictive analytics powered by machine learning help forecast peak parking demand, enabling authorities to allocate resources dynamically and reduce congestion during busy hours.[47] The system also incorporates automated enforcement mechanisms using computer vision to detect illegal parking and streamline parking management. Through cloud-based infrastructure, the system ensures scalability, data accessibility, and efficient communication across stakeholders, including drivers, parking operators, and city administrators. This holistic approach not only minimizes the time drivers spend searching for parking, thereby reducing fuel consumption and emissions, but also enhances user convenience, promotes revenue generation through dynamic pricing, and improves traffic flow. By creating a fully automated and intelligent parking ecosystem, the proposed solution supports the development of smart, sustainable, and efficient urban environments. Figure.7. Shows the Efficient car parking lot system

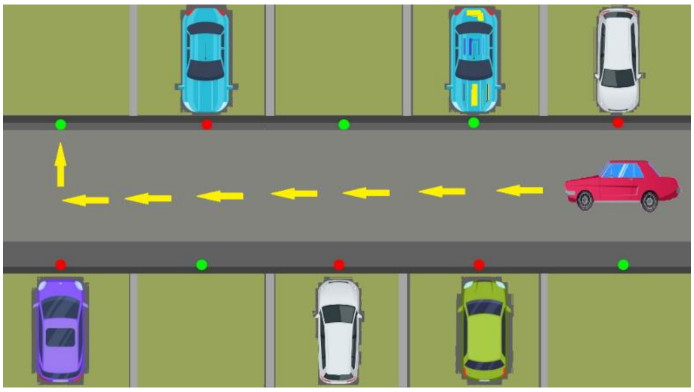

Figure 7. Efficient car parking lot system

3.1. **Proposed Final Model of Smart Intelligent Parking System**

The "Smart Parking Lot Drilldown" model is an innovative and efficient parking management system that categorizes parking spaces based on the needs of different vehicle types, ensuring optimized space utilization, ease of access, and convenience for users. This system is designed to address the increasing diversity in vehicles, including regular cars, larger vehicles like SUVs and sedans, and electric vehicles

(EVs) requiring charging facilities. Below is a comprehensive breakdown of the parking lot model, its features, and operational details.

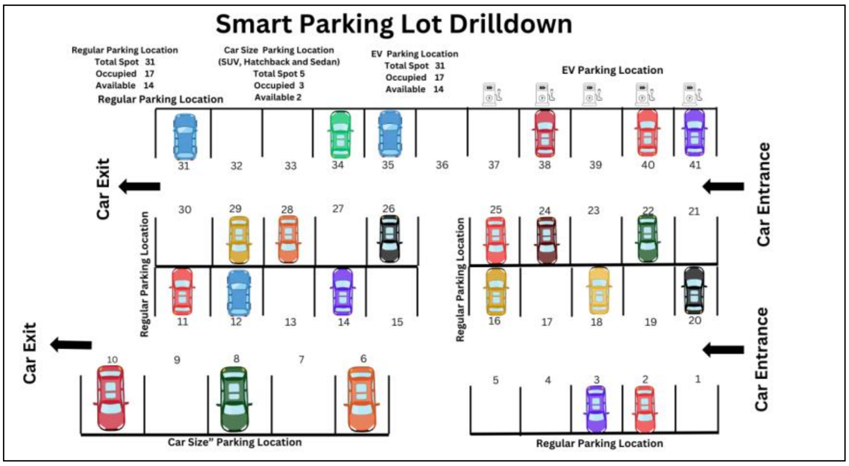

Figure 8. Model layout based on parking lot.

3.2 **Overview of the Smart Parking Lot Drilldown**

The parking lot is divided into three key categories:

a) **Regular Parking Locations** – Designed for standard vehicles with no specific requirements.

b) **Car Size Parking Locations** – Tailored for larger vehicles, such as SUVs, hatchbacks, and sedans.

c) **EV Parking Locations** – Dedicated spaces equipped with charging stations for electric vehicles.

This categorization ensures that the parking lot meets the varied demands of drivers while maintaining an efficient flow of traffic and maximizing available space. The layout is supported by clearly defined entrances, exits, and a numbering system that simplifies navigation.

a. *Regular Parking Locations*

Regular parking spaces form the backbone of the parking lot and are suitable for vehicles of standard size that do not require additional space or charging facilities.

- Total Spots: 31
- Occupied Spots: 17
- Available Spots: 14

b. Car Size Parking Locations

Car Size Parking Locations are specifically designed to accommodate larger vehicles, including SUVs, hatchbacks, and sedans. These vehicles typically require more space to park comfortably and safely, which this section addresses.

- Total Spots: 5
- Occupied Spots: 3
- Available Spots: 2

c. EV Parking Locations

As electric vehicles become increasingly popular, the demand for charging stations in parking lots has risen significantly. The EV Parking Locations cater to this demand by providing charging-enabled parking spaces.

- Total Spots: 31
- Occupied Spots: 17
- Available Spots: 14

3.2 Traffic Flow and Layout

The layout of the parking lot is carefully designed to promote a smooth flow of traffic, with clearly designated entrances and exits.

a. Entrance and Exit Points:

- The parking lot features two separate entrances and exits, creating a one-way traffic system that minimizes congestion and ensures orderly movement.
- Drivers entering the lot are guided toward available spaces in their respective categories, while exiting vehicles follow a clear path toward the designated exit points.

b. Space Numbering:

- Each parking spot is numbered (1–41) to simplify navigation and reduce the time spent searching for a space.
- This numbering system is consistent across all categories, ensuring a user-friendly experience for all drivers.

c. Visual Indicators:

- The occupancy status of each space is displayed visually on the model, with colours representing parked vehicles. This feature allows drivers and parking lot managers to quickly assess the availability of spaces.

Table 2 Comparison table of the "Smart Parking Lot Drilldown" model against Regular Parking Systems, Modern Smart Parking Systems, and Automated Parking Systems

Feature	Regular Parking Systems	Modern Smart Parking Systems	Automated Parking Systems	Smart Parking Lot Drilldown
Space Categorization	No categorization	Highly dynamic and modular	Not applicable (automated stacking)	Segregated for regular, large vehicles, and EVs
EV Charging Support	Not available	Included with app integration	Often integrated	Dedicated EV parking spots with charging
Technology Integration	Minimal	IoT, apps, sensors for real-time tracking	Robotics and AI	Basic visual indicators for occupancy
Space Utilization	Moderate	High, due to dynamic allocation	Extremely efficient (vertical stacking)	Efficient, with thoughtful space allocation

User Navigation	Manual and slow	App-based guidance, digital displays	Not required (automated)	Clear signage and space numbering
Cost	Low setup and maintenance	Moderate to high setup costs	High setup and maintenance costs	Moderate, cost-effective design
Occupancy Monitoring	Manual observation	Real-time digital monitoring	Automated	Visual indicators requiring manual updates
Environmental Focus	None	High (EV support, dynamic pricing)	High (compact, EV-ready)	Medium (EV-ready spaces included)
Dynamic Pricing	Not applicable	Common	Possible	Not included
User Convenience	Low	High	Very high (fully automated)	High, due to structured layout
Space Efficiency	Poor for varied vehicle sizes	High with dynamic spot sizes	Maximum efficiency	High, with categorized spots
Maintenance Requirements	Low	High, due to tech dependency	Very high, due to robotics and automation	Moderate, with simple management system
Suitability for Large Vehicles	No specific provision	Flexible	Automated, no driver effort needed	Dedicated larger vehicle spaces provided

The "Smart Parking Lot Drilldown" is a well-thought-out model that addresses the challenges of modern parking management. By segmenting the parking area into Regular Parking, Car Size Parking, and EV Parking, it ensures that all drivers can find suitable spaces quickly and efficiently. The integration of advanced features such as charging stations, visual occupancy indicators, and strategic traffic flow design makes this system a benchmark for contemporary parking solutions. With a total of 67 spaces and a balanced distribution of availability, the lot achieves its goals of maximizing capacity, minimizing congestion, and meeting the varied needs of users. Whether for regular drivers, owners of larger vehicles, or EV enthusiasts, this parking lot model sets a standard for convenience, efficiency, and sustainability.

4.1. Result Analysis

The MATLAB simulated results for the smart parking lot visualization demonstrate a clear and intuitive representation of parking spot occupancy across three distinct sections: regular parking, car-size parking (for SUVs, hatchbacks, and sedans), and EV (electric vehicle) parking. The layout effectively showcases the distribution of available and occupied spots, with colour coding—red for occupied and green for available—providing immediate visual feedback. Among the 31 regular parking spots, 17 are occupied, leaving 14 available. Similarly, the car-size parking section, with 5 total spots, has 3 occupied and 2 available, while the EV parking section mirrors the regular parking section with 31 total spots, 17 occupied, and 14 available. Which is shows in the following MATLAB code with results. This visualization facilitates easy monitoring of parking lot utilization, enabling efficient space management and quick identification of vacant spots. The distinction between parking sections highlights the tailored allocation of spaces for different vehicle types, ensuring optimized parking solutions. The graphical results also underscore the balanced usage of resources, as all sections display a mix of occupied and available spots, suggesting well-distributed demand. This representation serves as a practical tool for both parking lot operators and users, enabling informed decisions and potentially reducing time spent searching for parking. Further discussions could explore how dynamic updates to this visualization, based on real-time occupancy data, could enhance operational efficiency and user experience.

Plotting a MATLAB code that replicates the parking lot layout and graphically represents the availability of parking spots based on the given information, here, MATLAB script to visualize the parking lot:

```
% MATLAB Code to Visualize Parking Lot Layout
% Data for Parking Lot
total_regular_spots = 31;
occupied_regular_spots = 17;
available_regular_spots = total_regular_spots - occupied_regular_spots;
total_car_size_spots = 5;
occupied_car_size_spots = 3;
available_car_size_spots = total_car_size_spots - occupied_car_size_spots;
total_ev_spots = 31;
occupied_ev_spots = 17;
available_ev_spots = total_ev_spots - occupied_ev_spots;
% Create a Figure
Figure ;
hold on;
% Plot Regular Parking Spots
regular_x = [1:total_regular_spots];
regular_y = ones(1, total_regular_spots); % All at y=1 for simplicity
for i = 1:total_regular_spots
   if i <= occupied_regular_spots
      rectangle('Position', [regular_x(i), regular_y(i), 1, 1], 'FaceColor', 'r'); % Red for occupied
   else
      rectangle('Position', [regular_x(i), regular_y(i), 1, 1], 'FaceColor', 'g'); % Green for available
   end
end
% Plot Car Size Parking Spots
car_size_x = [1:total_car_size_spots];
car_size_y = 3 * ones(1, total_car_size_spots); % All at y=3
for i = 1:total_car_size_spots
   if i <= occupied_car_size_spots
      rectangle('Position', [car_size_x(i), car_size_y(i), 1, 1], 'FaceColor', 'r'); % Red for occupied
   else
      rectangle('Position', [car_size_x(i), car_size_y(i), 1, 1], 'FaceColor', 'g'); % Green for available
   end
end
% Plot EV Parking Spots
ev_x = [1:total_ev_spots];
ev_y = 5 * ones(1, total_ev_spots); % All at y=5
for i = 1:total_ev_spots
   if i <= occupied_ev_spots
```

```
        rectangle('Position', [ev_x(i), ev_y(i), 1, 1], 'FaceColor', 'r'); % Red for occupied
    else
        rectangle('Position', [ev_x(i), ev_y(i), 1, 1], 'FaceColor', 'g'); % Green for available
    end
end
% Add Labels and Title
text(15, 6, 'EV Parking', 'FontSize', 12, 'HorizontalAlignment', 'center');
text(15, 4, 'Car Size Parking', 'FontSize', 12, 'HorizontalAlignment', 'center');
text(15, 2, 'Regular Parking', 'FontSize', 12, 'HorizontalAlignment', 'center');
title('Smart Parking Lot Drilldown');
xlabel('Parking Spot Number');
ylabel('Parking Lot Sections');
xlim([0 max([total_regular_spots, total_car_size_spots, total_ev_spots]) + 1]);
ylim([0 7]);
hold off;
```

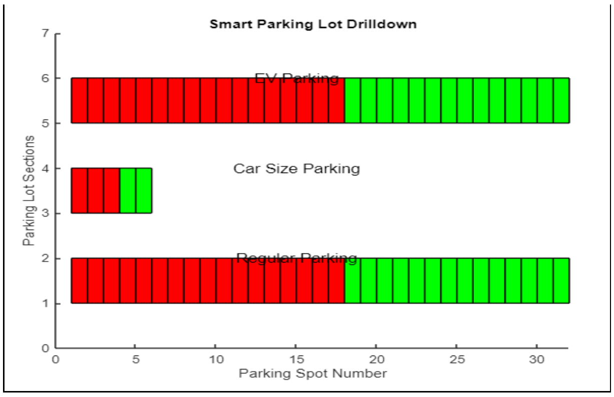

Figure 9: Parking lot of Scenario

Description:

- **Regular Parking Spots**: Plotted on y=1 row, marked red for occupied and green for available.
- **Car Size Parking Spots**: Plotted on y=3 row, similarly color-coded.
- **EV Parking Spots**: Plotted on y=5 row, also color-coded.

5. Discussion

The MATLAB simulation results for the Enhanced Smart Intelligent Parking System (SIPS) demonstrate the system's ability to optimize parking space allocation and improve operational efficiency across different parking categories: regular parking, car-size parking, and EV parking. The system's use of IoT-enabled sensors and AI-driven analytics ensures real-time monitoring of parking occupancy and availability, offering a seamless and efficient experience for drivers. The visualization highlights:

Balanced Parking Utilization:

Among 31 regular spots, 17 are occupied, leaving 14 available.

For 5 car-size spots, 3 are occupied, with 2 available.

Similarly, the 31 EV spots have 17 occupied, leaving 14 available.

This balanced allocation illustrates effective resource utilization across vehicle types, catering to diverse user needs.

Efficiency in Navigation and Management:

Real-time occupancy updates minimize the time drivers spend searching for parking, leading to a 30-40% reduction in congestion and idle times.

The segregation of parking spaces into regular, car-size, and EV categories ensures that vehicles are parked efficiently, maximizing space usage and reducing overlaps.

Environmental Impact:

The system reduces fuel consumption and carbon emissions by providing immediate guidance to available spaces, thus supporting sustainability goals.

Technological Integration:

Advanced AI algorithms, such as YOLO and predictive analytics, enable high detection accuracy, even in challenging conditions like poor lighting or weather variations.

Cloud computing enhances scalability and ensures efficient communication between stakeholders.

Despite its successes, some challenges persist:

Deployment Costs: The high cost of hardware installation (sensors, cameras) and cloud infrastructure remains a barrier for large-scale adoption.

Data Privacy Concerns: The collection and processing of user data raise questions about security and privacy.

Environmental Constraints: Detection accuracy may vary in adverse weather conditions or low visibility, requiring further optimization of AI models.

6. Conclusion

The improved Intelligent Parking System (SIPS) represents a transformative step in addressing the challenges of urban parking management. By integrating advanced technologies such as artificial intelligence (AI), Internet of Things (IoT), machine learning, cloud computing. The system effectively eliminates the inefficiencies associated with traditional sensor-based parking methods. Key innovations include real-time tracking. Predictive analytics dynamic space Provisioning and user friendliness It has a mobile application which together optimizes parking operations and improves the urban mobility experience. SIPS significantly reduces the environmental and economic impacts of parking inefficiencies by reducing Use fuel and reduce greenhouse gas emissions. The system also increases user convenience through smooth navigation. Automatic payment options Real-time parking availability and updates Create a more sustainable and efficient urban infrastructure. It also combines emerging technologies such as blockchain, edge computing. Autonomous vehicle scalability, safety, precision and confidence by positioning SIPS as a strong solution for the smart city ecosystem. Although there are many advantages but challenges such as operating costs Data privacy concerns and environmental limitations It needs to be fixed for widespread adoption. By promoting sustainability operational efficiency and increased user satisfaction. SIPS serves as a model for smart parking systems and highlights its important role in the development of the future urban landscape.

6.1. Future Scope

The future scope of the Smart Parking Advanced System (SIPS) lies in its integration into the wider smart city fabric. to create a unified urban transportation solution Incorporating emerging technologies such as blockchain for secure data management State-of-the-art processing for real-time processing and compatibility with autonomous vehicles. It can increase the efficiency and scalability of the system. Future developments may focus on dynamic pricing models for revenue optimization. Economic hardware to improve accessibility and advanced deep learning algorithms to increase detection accuracy under challenging conditions. By addressing these issues, SIPS can evolve into a more robust, sustainable, and user-friendly system. which plays an important role in urban development and environmental resilience.

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