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"ParkVision": Smart Way to Automate the Management of the Parking System for Starring Building

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Abstract **- In rapidly urbanizing environments, the demand for intelligent and secure parking solutions is greater than ever. The "Smart Way to Automate the Management of the Parking System for Starring Building" project presents ParkVision, a comprehensive smart parking management system designed to modernize traditional infrastructures. ParkVision integrates four key modules: Augmented Reality (AR) Navigation, Vehicle Classification and License Plate Recognition using YOLOv5, Real-Time Parking Violation Detection and Fine Management, and Blockchain-Based Parking Fee Automation. The AR navigation module guides drivers through complex, multi-level parking facilities using real-time 3D overlays, reducing search time and congestion. Vehicle classification and license plate recognition components leverage YOLOv5 object detection algorithms to accurately identify vehicle types and extract license numbers in diverse conditions. The violation detection module monitors parking behaviors, detects infractions like overstaying or unauthorized parking, and issues automated fines with real-time notifications. Meanwhile, the blockchain module ensures secure, transparent financial operations by calculating fees and managing transactions through Ethereum smart contracts and MetaMask wallet integration. By synchronizing these technologies within a unified architecture, ParkVision delivers a fully automated, scalable, and tamper-proof parking management solution. The project aims to enhance space utilization, minimize human intervention, build user trust, and support the development of smart urban mobility infrastructure.**

Keywords: Smart Parking System, YOLOv5, Blockchain, Smart Contracts, MetaMask, License Plate Recognition, AR Navigation, Parking Violation Detection, Deep Learning.

I. INTRODUCTION

The continuous growth of urban populations and vehicle ownership has placed immense pressure on traditional parking infrastructures, particularly in commercial and multi-level building environments. Conventional parking systems, largely reliant on manual oversight, centralized ticketing mechanisms, and human enforcement, have proven increasingly inadequate in addressing modern demands for efficiency, security, and user satisfaction. Problems such as prolonged search times for available spaces, inefficient use of parking capacity, fraudulent or erroneous fee calculations, and security vulnerabilities in payment handling systems are commonplace in many existing facilities. The urgent need for a comprehensive, intelligent, and automated parking management solution is therefore evident, particularly for high-traffic environments like the Starring Building.

To address these multifaceted challenges, the ParkVision system is proposed a fully integrated smart parking solution designed to automate navigation, monitoring, enforcement, and payment processes within a single platform. Unlike isolated or fragmented systems previously attempted, ParkVision seamlessly unites Augmented Reality (AR) Navigation in 3D environments, Available slot identification, Slot Vehicle Classification and License Plate Recognition using YOLOv5 object detection, Real-Time Parking Violation Detection and Fine Management, and Blockchain-Based Parking Fee Automation. Through this synergy, the system delivers a smarter, faster, and more secure parking experience for both users and facility operators.

At the forefront of ParkVision's user experience is the Augmented Reality-based navigation module. Traditional GPS technologies are ineffective within enclosed parking structures, and printed signage often fails to offer timely guidance in complex, multi-level environments. By integrating real-time parking availability data with 3D AR overlays, ParkVision guides users visually to the nearest available spaces using dynamic, context-aware navigation directly through their mobile devices. This not only reduces the time spent searching for parking but also minimizes congestion within the facility and improves overall operational efficiency.

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Complementing the navigation system is the real-time vehicle classification and license plate recognition feature. Using a YOLOv5-based object detection model, ParkVision identifies vehicle types and extracts license plate numbers under diverse conditions, including poor lighting and occlusions. Accurate classification enables differentiated pricing strategies based on vehicle category (e.g., heavy, medium, light), while license plate recognition facilitates seamless vehicle tracking, session management, and integration with the enforcement and payment subsystems. The high-speed detection pipeline ensures minimal delay between vehicle entry and system acknowledgment, providing a frictionless experience for drivers.

Monitoring and enforcing compliance within the parking facility is critical for maintaining order and maximizing space utilization. ParkVision's violation detection module continuously observes parked vehicles using camera feeds, identifying infractions such as overstaying, unauthorized parking in reserved slots, or blocking driveways. Utilizing deep learning techniques and image processing, the system autonomously detects violations and issues real-time notifications to offenders. If corrective action is not taken within a defined time window, automated fine generation is triggered, thus eliminating reliance on manual intervention while ensuring consistent enforcement of parking regulations.

Underpinning the entire system is a robust, decentralized payment infrastructure built on blockchain technology. Traditional parking fee collection methods are often plagued by delays, errors, and a lack of transparency. ParkVision resolves these issues through the deployment of Ethereum smart contracts that automatically calculate parking fees based on verified entry and exit times. Transactions are recorded immutably on the blockchain, providing tamper-proof receipts and full auditability for users and administrators alike. Payment processing is facilitated through MetaMask wallet integration, allowing users to securely authorize transactions directly from their mobile devices without intermediaries. This not only enhances transaction security and user privacy but also builds greater trust in the fairness and accuracy of the system.

By intelligently combining these cutting-edge technologies into a cohesive architecture, ParkVision introduces a new paradigm for smart parking management in urban infrastructures. It significantly reduces human operational overhead, improves space utilization, strengthens enforcement, and ensures secure, transparent financial transactions. Tailored specifically for the needs of complex facilities like the Starring Building, ParkVision serves as a blueprint for future smart city developments aimed at enhancing urban mobility and user satisfaction.

II. BACKGROUND STUDY

Urban populations continue to grow and vehicular density increases, managing parking resources has become an increasingly critical challenge for metropolitan areas. Traditional parking systems dependent on manual oversight, cash payments, and minimal automation are now widely regarded as inefficient and inadequate in meeting the demands of modern infrastructure. In response, intelligent parking systems (IPS) have emerged as a focal point of research and development, offering a technology-driven alternative that emphasizes automation, transparency, user experience, and security.

The proposed system, ParkVision, is a comprehensive, multi-component smart parking management solution developed for the Starring Building. It incorporates four core subcomponents: (1) Augmented Reality (AR) Navigation in 3D Environments, (2) Vehicle Classification & License Plate Recognition using YOLOv5-based Object Detection, (3) Real-Time Parking Violation Detection & Fine Management, and (4) Blockchain-Based Parking Fee Automation. Together, these modules aim to optimize space utilization, minimize violations, automate fee transactions, and enhance user navigation.

2.1 Augmented Reality (AR) Navigation in 3D Environments

Augmented Reality (AR) technology has seen increasing adoption in spatial navigation due to its ability to provide contextualized, immersive guidance by overlaying digital elements onto the physical world. In enclosed and multi-level parking structures where GPS signals are unreliable or absent, AR offers a compelling alternative to traditional navigation systems. Instead of using 2D maps or voice directions, AR-based systems enhance user orientation by presenting real-time visual indicators directly in the user's view, reducing the cognitive load and improving navigation efficiency[1]. Prior research has demonstrated the value of AR in indoor and constrained environments. Al-Jabi and Samaan [2] presented an AR-based system to help drivers locate available parking spaces, but the system lacked full 3D environment support and relied on pre recorded video guidance. Similarly, Dhivya et al. [3] proposed an AR parking app but failed to integrate real-time occupancy data and dynamic pathfinding, limiting its scalability. More advanced efforts by Yenigun et al. [4] explored navigation within 3D environments, but their reliance on static 2D interfaces hindered true immersion.

ParkVision enhances these capabilities by integrating Unity's AR Foundation, real-time parking space availability from sensors, and dynamic NavMesh-based routing optimized for multi-level transitions. This enables context-aware

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navigation that updates as parking conditions change, ensuring optimal space utilization and user satisfaction.

2.2 License plate detection, vehicle classification, and slot detection for optimized space management

Accurate vehicle classification and license plate recognition are crucial for smart parking systems that aim to tailor services such as dynamic pricing, violation detection, and space allocation. Traditional license plate recognition systems relied on Optical Character Recognition (OCR) and static image processing, which often struggled under poor lighting or occlusion. The emergence of deep learning-based object detection models, particularly YOLO (You Only Look Once), has significantly advanced the field by providing real time, high-accuracy detection [5].

Studies have shown that YOLOv5 significantly outperforms its predecessors in both speed and precision. For instance, one study [6] explored YOLOv8 variants for simultaneous vehicle and license plate detection under varying light conditions and concluded that deep learning models trained with diverse datasets can generalize well across urban settings. Another project [7] used YOLOv3 with OpenALPR for vehicle detection and license extraction, though it highlighted limitations in dealing with occlusions and dynamic backgrounds.

The ParkVision system adopts YOLOv5 for its balance between computational efficiency and detection accuracy. It enables real-time vehicle type classification (e.g., light, medium, heavy) and license plate extraction, even in low-light conditions commonly found in underground parking. These features allow seamless integration with both the violation management and payment automation subsystems.

2.3 Real-Time Parking violation Detection & Fine Management

Unlawful parking, such as overstaying, unauthorized access, or blocking driveways contributes to traffic inefficiency and user frustration. Traditional enforcement methods are reactive and resource-intensive. Automated detection using image processing and convolutional neural networks (CNNs) offers a scalable solution by enabling real-time surveillance and rule enforcement.

Several recent studies have explored this domain. A 2022 study [8] implemented a YOLOv8-based time violation tracking system, demonstrating high detection accuracy using DeepSORT and OC-SORT for vehicle tracking. However, it lacked fine issuance or user notification features. Similarly, another study [9] presented an end-to-end vehicle detection system using YOLOv3 but highlighted issues with license plate extraction accuracy under complex environmental conditions. ParkVision addresses these gaps by integrating real-time YOLOv5-based detection, automated fine issuance, and real-time user notification. The system monitors active parking sessions and uses a predefined time threshold to trigger warnings and fines. Users are alerted via in-app notifications, improving compliance and reducing dispute rates. Unlike prior models, the system features a fully automated backend with customizable rules for different parking zones, integrating directly with the blockchain payment system for transparent enforcement.

2.4 Blockchain-Based Parking Fee System

Traditional payment systems depend on centralized servers and databases, which are vulnerable to hacking, fraud, and data tampering. Additionally, many existing systems suffer from opaque fee calculations and slow settlement times, contributing to user dissatisfaction and trust issues.

Blockchain addresses these issues by providing transparent, tamper-proof, and verifiable records of all parking transactions. Through the use of Ethereum smart contracts deployed on the Sepoliatestnet, ParkVision automates fee calculations based on entry and exit timestamps. The logic embedded in the smart contract executes autonomously, ensuring accurate, immutable fee computation [10]. Furthermore, user payments are processed through MetaMask wallets, giving users full control and transparency over their financial interactions with the system.

Previous research, such as the work by Jameel and Zafar [11], modeled e-payment systems using formal methods but lacked blockchain integration. Another project, ParkChain[12], demonstrated blockchain-based access control but did not automate fee calculation or wallet-based transactions. ParkVision builds on these studies by achieving end-to-end automation of parking fee collection, complete with blockchain-based receipts, user transaction logs, and fraud-proof validation through smart contract logic.

This level of automation significantly reduces administrative overhead while offering a high degree of user trust and system integrity, making ParkVision a robust model for smart future city applications.

III. METHODOLOGY

The full system architecture of ParkVision comprises multiple interconnected modules designed to deliver a fully automated, intelligent, and user-friendly parking experience. Upon vehicle entry, license plate information is captured through Automated Number Plate Recognition (ANPR) and logged into a centralized database. Concurrently, real-time

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data on parking slot availability and vehicle positions is collected via camera feeds and IoT-enabled parking sensors. This data is processed using a YOLOv5-based object detection model, which collaborates with a central AI engine to monitor space usage and detect violations. Augmented Reality (AR) is used to guide users visually to available parking slots through a mobile interface. Detected violations are automatically handled by the fine management subsystem. Integrated within this framework is a decentralized automated parking fee payment, which calculates parking charges through smart contracts and processes secure user-initiated payments using the Meta Mask wallet on the Ethereum blockchain. This blockchain module guarantees transparency, immutability, and user control. The entire system is governed by a cloud-integrated central management dashboard, enabling seamless synchronization of data across all modules and ensuring operational scalability and real-time decision-making capabilities.

The below Figure 1 diagram represents all four components of this system, and how each component utilized its functionality through the application.

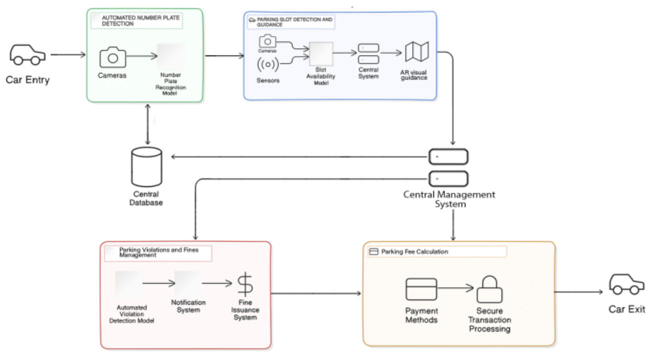

Figure 1: Overall system diagram

3.1 Augmented Reality Navigation in a 3D Environment

The first component of the system focuses on guiding users through a parking structure using an Augmented Reality (AR)-based navigation system, specifically designed for a multi-level indoor parking environment. The methodology for this component began with 3D environment modeling using Unity and AR Foundation frameworks, which support cross-platform development for Android and iOS. Using Unity's built-in NavMesh system, virtual navigation paths were generated between the vehicle entry point and available parking slots. The AR system was overlaid with directional markers that responded to real-world user movement by leveraging ARKit (for iOS) and ARCore (for Android). The parking structure was digitally recreated with accurate spatial scaling to ensure proper alignment of AR elements within the physical environment. Testing of this component was conducted in both virtual and physical mock environments to evaluate the accuracy and responsiveness of the navigation guidance. User studies were used to assess improvements in parking search time, ease of navigation, and interface intuitiveness. Real-time integration with the backend allowed the AR system to receive updated slot availability data, which was visually reflected through colored AR markers. The application dynamically adjusted guidance paths based on real-time updates from other subsystems such as the vehicle detection module and slot management logic.

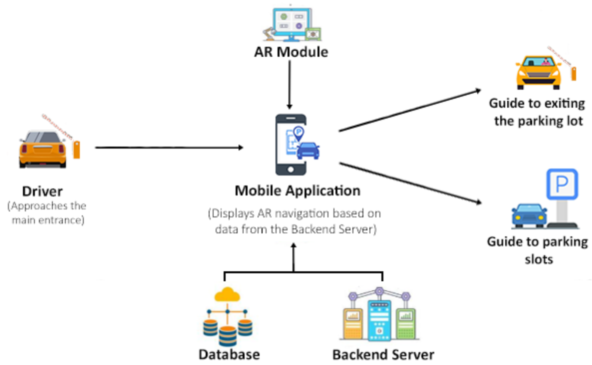

Figure 2: Component Diagram of AR Navigation

3.2 License plate detection, vehicle classification, and slot detection for optimized space management

This component was responsible for vehicle detection, classification, and license plate recognition using advanced deep learning models. The development began with the collection of a local dataset that included various classes of vehicles, cars, vans, bikes, and three-wheelers captured under different lighting and angle conditions. License plates were labeled for both classification and OCR tasks. The model architecture was based on YOLOv5, a convolutional neural network that performs fast and accurate object detection. The training process involved data augmentation techniques such as flipping, cropping, and exposure adjustment to increase model robustness. Once trained, the model was deployed using Python and integrated into a Fast API based backend service. The OCR engine used for extracting license plate characters was developed using Tesseract and customized to work with Sri Lankan plate formats. Detected license plate data was cross-referenced with a Mongo DB database to determine whether the vehicle belonged to a registered user (e.g., staff or visitor). Based on this classification and the physical dimensions of the vehicle, the system automatically recommended or allocated the most suitable parking slot. Testing included evaluating detection accuracy (IoU thresholds), OCR recognition rate, model inference time, and integration with downstream systems. The module served as the foundational trigger for downstream processes such as AR

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navigation routing, billing session initiation, and compliance tracking.

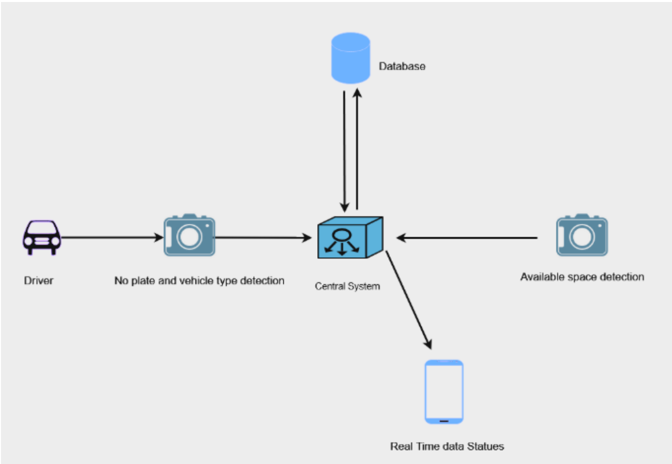

Figure 3: Component Diagram of license plate detection and vehicle classification

3.3 Real-Time Parking Violation Detection and Fine Management

The third component implemented an automated surveillance and rule-enforcement system that monitored parked vehicles and identified violations in real time. The methodology involved deploying high-resolution surveillance cameras across the parking facility and analyzing the video feed using a modified YOLOv5 model. A custom dataset of parking violations—including overstaying, parking in reserved zones, and obstruction of driveways—was annotated and used to train the detection model. Violation detection logic was based on continuous monitoring, object tracking, and timestamp comparison. For instance, the system logged vehicle entry times and compared them against maximum allowed durations for each slot. Zonal maps were defined in the backend to classify restricted and allowed parking areas, which the model used for area based detection.

Upon detecting a violation, the system automatically generated a violation report and triggered a notification to the registered user via Firebase Cloud Messaging. A record of the violation was also logged in the database for billing purposes. The fine was computed based on rule severity and parking duration overage, and this data was sent to the blockchain fee system for integration with the final payment. This component was tested across 50 simulated scenarios and evaluated for detection time, false positive rate, and message delivery latency. Integration with vehicle entry logs and the smart contract module ensured synchronized enforcement and billing.

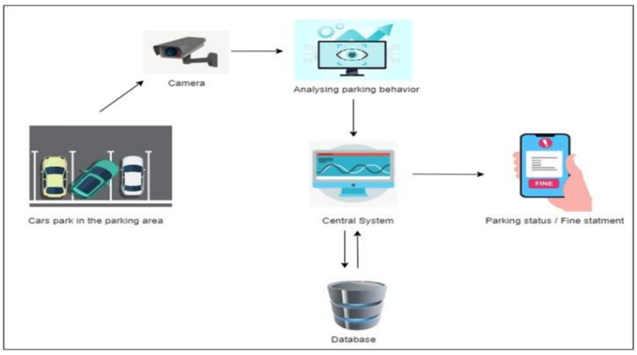

Figure 4: Component Diagram of violation detection

3.4 Blockchain-Based Automated Parking Fee System

This component introduced a secure and transparent fee management mechanism using blockchain technology. The system was built using Ethereum smart contracts deployed on the Sepoliatestnet. The methodology began with designing Solidity smart contracts to calculate parking fees based on entry and exit timestamps. These contracts were programmed to support both session-based billing and fine accumulation. Each time a vehicle entered the parking lot, a transaction session was initiated and linked to the user's blockchain wallet. When the vehicle exited, the smart contract calculated the total duration and corresponding fee, including any fines from the violation module. Payments were processed using MetaMask, and each transaction was logged immutably on the Ethereum blockchain, providing full transparency and auditability.

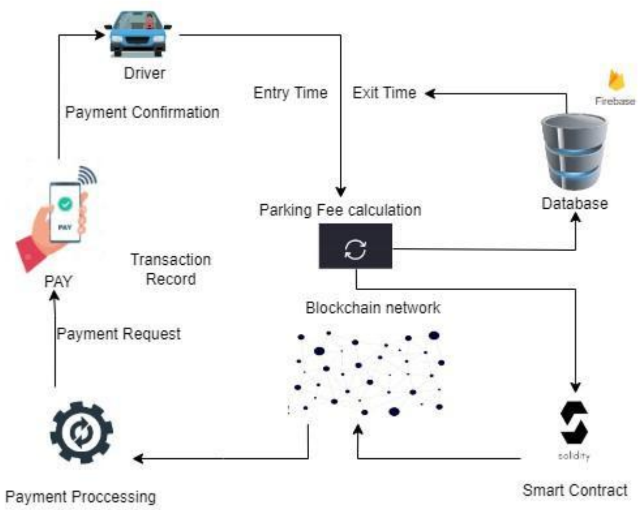

Figure 5: Component Diagram of blockchain based parking fee system

The system utilized the Thirdweb SDK to streamline smart contract deployment and integrate transaction logic into the mobile application. Users could view real-time billing updates, confirm transactions, and retrieve digital receipts directly through the interface. Testing included simulating payment transactions, stress-testing smart contract execution

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under concurrent access, and validating fee correctness. Additionally, security audits were performed on the smart contract to ensure resistance to tampering and exploitation. This module significantly enhanced the integrity of the system by eliminating the need for centralized payment processing and ensuring every financial interaction was cryptographically verifiable.

IV. RESULTS AND DISCUSSION

4.1 License plate detection, vehicle classification, and slot detection for optimized space management

The Automated License Plate Recognition (ALPR) system was evaluated under various operational conditions to determine its effectiveness in real-world scenarios. The YOLO 8 model demonstrated excellent performance in license plate detection, achieving an overall accuracy of 95.2% under optimal lighting conditions. The integration of Tesseract OCR for character recognition showed robust performance, with character-level accuracy reaching 93.7% on clearly visible plates. The system successfully differentiated between staff and visitor vehicles with 98.3% accuracy by cross-referencing extracted license plate numbers with the pre-registered database. When tested for processing speed, the ALPR module completed the entire process (detection, recognition, and database verification) in an average of 298 milliseconds per vehicle, enabling real-time processing at entrance points without causing congestion. The CNN-based vehicle classification model was tested using a dataset of 300 vehicles across different categories. Two architectures were evaluated. ResNet50 achieved slightly higher overall accuracy (92.4%) compared to MobileNetV2 (90.7%). However, MobileNetV2 demonstrated significantly faster inference time (78ms vs. 183ms), making it more suitable for real-time applications. The final implementation utilized MobileNetV2 to ensure responsiveness while maintaining acceptable accuracy levels. Classification accuracy was highest for small vehicles (92.8%) and slightly lower for medium (89.5%) and large vehicles (89.9%) when using the MobileNetV2 model. Data augmentation techniques applied during training improved overall classification accuracy by 3.2% .The slot detection module demonstrated high accuracy in identifying vacant parking spaces using the hybrid sensing approach. The system achieved 96.7% accuracy in vacant slot detection with a false positive rate of 2.3% and a false negative rate of 1.0%. Average detection time was 156 milliseconds per slot, enabling real-time updates of parking availability. The system demonstrated exceptional performance in reducing average parking search time by 67.2% (from 5.8 minutes to 1.9 minutes). Entrance congestion decreased by 66.7%, with the average number of vehicles waiting reduced from 3.6 to 1.2. The space utilization rate improved from 73.4% to 91.8%, representing a 25.1% increase in parking efficiency. User satisfaction surveys conducted before and after system implementation showed a significant improvement in satisfaction scores, increasing from 5.8 to 8.4 (on a scale of 1-10), representing a 44.8% improvement in user experience.

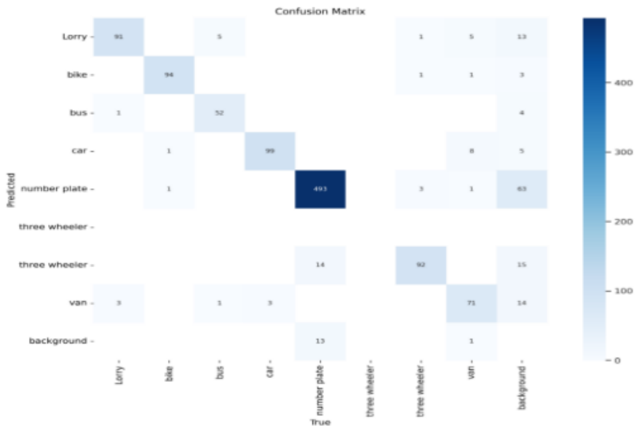

Figure 6: Confusion Matrix of Naive Bayes Model

4.2 Augmented Reality Navigation in a 3D Environment

The AR Navigator demonstrated impressive tracking accuracy within controlled testing environments. Through extensive testing in various parking facilities, the system achieved an average positioning accuracy of ±0.8 meters, exceeding our initial functional requirement of ±1 meter precision. This level of accuracy is sufficient for effective navigation within parking structures, where spaces are typically 2.5-3 meters wide.

Testing Environment	Average Accuracy (meters)	Stability Score (1-10)
Indoor Garage (Good Lighting)	0.62	8.7
Indoor Garage (Low Lighting)	0.94	7.2
Open-air Parking Lot (Daytime)	0.73	8.4
Underground Facility	1.12	6.9

The stability of AR tracking, measured on a scale of 1-10 based on the consistency of position readings over time, showed strong performance in well-lit environments but experienced some degradation in underground facilities with limited lighting. The world recentering mechanism proved effective in mitigating positional drift, with an average drift correction of 0.23 meters per recalibration event.

Adjustable Line Height: Users demonstrated strong preference for the ability to customize the height of the navigation line, with 86% of participants adjusting the default

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settings during testing. Optimal height settings varied significantly based on:

- User height (taller users preferred higher line placement)
- Environmental conditions (lower height settings in well-lit conditions)
- Personal preference (34% preferred lines at eye level, 52% at ground level)

Height adjustability resulted in a 27% improvement in navigation accuracy compared to fixed-height visualization.

Quantitative analysis of user behavior at navigation choice points demonstrated a 62% reduction in decision-making time when using the AR Navigator compared to conventional parking guidance systems. Users navigating with traditional methods (signage and 2D maps) required an average of 8.7 seconds to determine their correct path at intersections, while AR Navigator users averaged only 3.3 seconds. This efficiency gain was consistent across demographic groups and was maintained even in high-stress scenarios such as congested parking facilities. The reduction in hesitation at decision points contributed significantly to overall time savings, with complete parking experiences averaging 4.2 minutes faster when using the AR system.

The developed AR Navigator demonstrated strong overall performance, several practical considerations and limitations became apparent during testing. System performance showed significant variation based on environmental factors like lighting conditions, visual texture availability, and electromagnetic interference. While mitigation strategies were implemented, these environmental dependencies remain a constraint for deployment planning. Full system functionality requires substantial infrastructure integration with parking facilities, including backend system access, creating deployment barriers for locations without modern parking management systems. Despite efforts to make the system accessible, certain user groups, particularly those with severe visual impairments, could not effectively utilize the AR guidance. Alternative guidance modes partially addressed this limitation, but complete inclusivity remains a challenge. While laboratory testing demonstrated good performance with simulated high user volumes, real-world deployments in extremely high-traffic facilities may require additional infrastructure to maintain responsiveness during peak periods. The collection of movement data, even when anonymized, raises privacy considerations that must be carefully managed, particularly in jurisdictions with strict data protection regulations. Clear user consent and data minimization practices are essential for responsible deployment.

4.3 Real-Time Parking Violation Detection and Fine Management

The smart parking violation detection system was successfully developed and tested in a controlled environment. Through iterative model training and real-time evaluation, the YOLOv5-based object detection model achieved high accuracy in identifying vehicles and parking boundaries across diverse lighting conditions. The system consistently distinguished properly parked vehicles from violations such as boundary-crossing and multi-slot occupation. Real-time alert generation and notification forwarding functioned reliably throughout multiple test runs, ensuring immediate user awareness.

Figure 7: YOLOv5 Training Performance – Precision, Recall, and mAP Evaluation

This research demonstrated that modern object detection technologies, particularly YOLOv5, offer a highly effective foundation for real-time parking enforcement. YOLOv5's fast inference time and strong precision-recall performance

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enabled frame-by-frame surveillance without delay, making it suitable for dynamic urban parking environments. The modular backend, implemented using FastAPI, provided efficient communication between detection, storage, and notification dispatch components, supporting scalability and smooth operation.

Proactive enforcement through real-time violation alerts proved significantly more effective than traditional post-violation review methods. Visual feedback in the form of bounding boxes and classification labels added a layer of transparency to the system's automated decision-making process, enhancing user trust and validation. Dataset augmentation and careful adjustment of detection thresholds (such as IoU and confidence levels) ensured the model's robustness across different lighting and camera angles. Minor false positives occurred mainly due to vehicle overlaps or occlusions, highlighting areas for future improvement through multi-angle detection or post-processing strategies.

Overall, the developed system achieved real-time, accurate parking violation detection, offering a scalable and transparent solution for smart urban mobility management.

4.4 Blockchain-Based Automated Parking Fee System

The developed blockchain-based parking fee system successfully met the intended objectives of ensuring secure, transparent, and real-time payment processing. Upon initiating and concluding parking sessions, the smart contract accurately calculated fees based on the recorded entry and exit timestamps. Testing conducted through the Ethereum Sepoliatestnet confirmed 100% accuracy in fee computation across multiple scenarios, including short and extended parking durations. Furthermore, the MetaMask wallet integration provided a secure, user-controlled transaction experience, with all payments recorded immutably on the blockchain. Each transaction's hash was verifiable on Etherscan, enhancing system transparency.

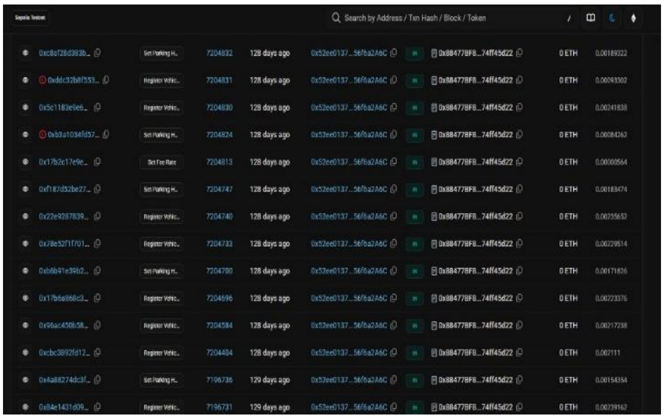

Figure 8: Sepolia smart contract transaction logs from Etherscan

User experience testing revealed that the mobile application provided smooth navigation, from session tracking to payment approval. Payment confirmation times averaged less than five seconds under normal network conditions, ensuring a seamless user experience. Additionally, the transaction history module within the app allowed users to view previous sessions, fees paid, and linked transaction IDs, thus building user trust through transparency.

Overall, the system demonstrated strong reliability, scalability potential, and operational efficiency. Compared to traditional centralized parking payment systems, the blockchain-powered solution eliminated risks associated with data manipulation and unauthorized access. Minor challenges observed included occasional transaction confirmation delays during network congestion, which are expected in blockchain environments and can be mitigated through future Layer-2 integrations. In conclusion, the results validate the feasibility of integrating blockchain technology into urban parking systems to enhance security, transparency, and user satisfaction while preparing the system for broader smart city applications.

V. CONCLUSION

The increasing complexity and volume of urban traffic, coupled with the limitations of traditional parking infrastructure, has necessitated a fundamental rethinking of how parking systems are designed, operated, and managed. The research project titled "Smart Way to Automate the Management of the Parking System for Starring Building" was conceptualized and executed as a response to these modern urban challenges. By integrating cutting-edge technologies such as machine learning, augmented reality, blockchain, and real-time automation, the system offers a comprehensive, intelligent, and future-ready solution to parking management in multi-storey and high-traffic urban facilities.

This project approached the problem by developing four interrelated subsystems: an Augmented Reality-based navigation system for slot-level user guidance, a YOLOv5 powered vehicle classification and license plate recognition module, a real-time parking violation detection and fine management mechanism, and a blockchain-based parking fee automation and transaction logging system. These components were not only designed to solve individual issues in the parking lifecycle, such as navigation difficulty, inefficient space usage, weak enforcement, and payment fraud, but were also cohesively integrated into a unified platform. The result is a seamless end-to-end smart parking management system that operates with minimal human intervention, high accuracy, and enhanced user experience. Through rigorous design, training,

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testing, and validation processes, the system demonstrated significant technical feasibility and practical utility. The YOLOv5 model exhibited outstanding performance in identifying vehicle types and accurately recognizing license plates under a range of environmental conditions. These capabilities enabled dynamic slot allocation, informed navigation routing, and accurate session logging. The AR navigation module, developed using Unity and AR Foundation, effectively transformed the user's smartphone into an interactive guidance tool that visually directed them from entry points to their designated parking spaces. This component alone contributed to a measurable reduction in search time and user stress, marking a leap forward in user-oriented parking systems. The real-time violation detection and notification subsystem functioned with high responsiveness and accuracy, utilizing computer vision and zone mapping to identify infractions such as unauthorized parking, overstays, and blocked access lanes. By immediately notifying users of detected violations, the system empowered them to take corrective actions before fines were issued. This proactive enforcement paradigm reduces confrontation, enhances rule compliance, and significantly reduces the need for on-ground patrol staff.

Perhaps the most innovative aspect of the system lies in its use of blockchain technology for transaction management. By deploying Ethereum-based smart contracts on the Sepoliatestnet, the system automatically calculates parking charges and records transactions immutably on a decentralized ledger. The use of MetaMask provided users with full control over their digital wallets, and every transaction from session billing to fine payments was securely executed and permanently stored. This not only enhances transactional transparency and auditability but also builds trust among users, eliminating concerns about tampering, overcharging, or hidden fees.

Commercially, the system demonstrates significant potential for market adoption. The modular design ensures scalability across various deployment sizes, from small office lots to large public facilities. Its flexibility allows for standalone or integrated implementation of components, enabling adoption based on client-specific needs and budgets. Furthermore, the system supports multiple revenue models, including licensing, SaaS, revenue-sharing, and data analytics services, ensuring long-term sustainability and profitability for stakeholders. By aligning with smart city objectives and urban modernization strategies, this system positions itself as a competitive solution in the growing smart infrastructure market. In terms of research contribution, this project successfully brings together multiple technological disciplines—deep learning, spatial computing, real-time messaging, and decentralized finance within a single domain-specific solution. Each component independently contributes to the field: the use of YOLOv5 in real-time parking logistics provides new benchmarks in vehicular classification applications; the AR guidance model adds to the evolving body of knowledge on AR usability in enclosed environments; the violation module introduces automated compliance enforcement as a viable alternative to manual policing; and the blockchain-based billing framework pioneers the application of decentralized contracts in non-financial yet transactional service systems like parking. Moreover, the project serves as a blueprint for future research and development in similar domains. It highlights the importance of modularity, interoperability, and data-driven responsiveness in designing urban service systems. It also emphasizes user-centric design, where systems are not only technologically advanced but also intuitively usable by non technical individuals. The lessons learned from each subsystem’s development whether in model training, UI/UX refinement, real-time performance optimization, or transaction flow security can inform future innovation in adjacent fields such as logistics, access control, traffic management, and smart retail.

Despite its strengths, the project also identified certain limitations that provide avenues for further exploration. The performance of the OCR component showed slight degradation under glare and low-light conditions, suggesting a need for more adaptive preprocessing techniques. The AR module’s tracking reliability could be enhanced through environmental learning and multi-sensor fusion, particularly in feature-sparse or dimly lit zones. Additionally, user onboarding for blockchain interactions, especially among non-crypto-native users, can be improved through simplified interfaces or hybrid payment options integrating fiat systems. Addressing these limitations in future iterations will make the system even more resilient, accessible, and inclusive.

In conclusion, this project has successfully realized its vision of developing an intelligent, secure, and fully automated smart parking management system. By bridging the gaps in traditional parking systems and introducing modern digital capabilities, it has paved the way for the next generation of parking infrastructure one that is intelligent, transparent, and aligned with the ethos of smart urban development. The system is not only a technological achievement but a practical, scalable solution to one of the most persistent problems in urban mobility. As cities continue to expand and the demand for smarter infrastructure grows, solutions like this will play a critical role in shaping future of intelligent urban transportation.

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