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# IPS: Intelligent Parking System Using YOLO and Image Processing

Ruchi Rani[1*], Sumit Kumar[2], Sanjeev Kumar Pippal[3], Mrunal Gund[1], Ulka Chaudhari[1], Riya Agrawal[1], Megha Dalsaniya[1], Lisa Verma[1]

[1] Department of Computer Engineering and Technology, School of Computer Engineering and Technology, Dr. Vishwanath Karad MIT World Peace University, Pune 411038, India
[2] Symbiosis Institute of Technology, Pune Campus, Symbiosis International (Deemed University), Pune 411045, India
[3] GL Bajaj Institute of Technology and Management, Greater Noida 201306, India

Corresponding Author Email: ruchiasija20@gmail.com

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**ABSTRACT**

Parking management systems often need to improve due to outdated infrastructure, inefficient manual processes, and the lack of automation, resulting in increased congestion and poor user experience. Traditional parking management systems, reliant on manual license plate entry and outdated payment methods, need help to meet modern demands. In response, this research introduces a novel Intelligent Parking System (IPS) that leverages automatic License Plate Recognition (LPR) with a YOLO model for real-time detection and recognition of vehicle license plates. By eliminating the need for sensors and manual data entry, our system enhances accuracy, reduces maintenance costs, and optimizes parking operations. Furthermore, integrating QR code-based payment simplifies and accelerates the payment process, reducing wait times and improving user experience. This approach addresses the growing need for scalable and adaptable parking solutions in smart city initiatives. Through this research, the IPS provides a scalable, intelligent alternative to conventional parking systems, contributing to smarter urban environments.

## 1. INTRODUCTION

Parking management systems are critical in urban environments, where the exponential growth of vehicles has led to significant parking challenges [1, 2]. The limitations of traditional parking management methods, which often rely on manual entry of license plate numbers and outdated, inefficient payment processes, are becoming increasingly evident. These systems struggle to keep pace with the demands of modern urbanization, leading to operational inefficiencies, revenue leakage, and user dissatisfaction. In response to these challenges, there is a growing need for more intelligent, automated solutions to address the complexities of contemporary parking systems. Our research introduces an Intelligent Parking System (IPS) designed to bridge this gap by integrating cutting-edge technologies such as automatic License Plate Recognition (LPR) and YOLO-based object detection [3-5], providing a more efficient, scalable, and accurate solution.

Unlike traditional methods, our IPS leverages real-time LPR with the YOLO model, a high-performance object detection algorithm, to swiftly and accurately capture license plate numbers upon vehicle entry [6-9]. This automation eliminates the need for manual input and significantly streamlines the parking process, addressing a key challenge of traditional systems: human error. By integrating this advanced detection system, the IPS eliminates the need for sensors, simplifies infrastructure, and reduces maintenance costs, enhancing its practicality in large-scale urban deployments.

One of the significant areas for improvement of older parking systems is the potential for revenue leakage due to inaccuracies in manual license plate entry or reliance on outdated technologies. Our IPS enhances billing accuracy, ensuring that all vehicles are correctly charged for parking time, thereby preventing revenue losses for parking operators. Additionally, the system improves operational efficiency by reducing the reliance on labor-intensive processes and enhancing data accuracy.

Furthermore, our IPS significantly enhances user convenience by integrating QR code-based payment systems [10] at the point of exit, bypassing the need for traditional payment terminals and reducing waiting times. This seamless payment process improves the user experience and decreases congestion at parking exits, contributing to overall system efficiency. Through extensive simulations and real-world deployments, our research demonstrates the IPS's efficacy in optimizing space utilization, reducing congestion, increasing revenue accuracy, and improving user satisfaction.

Unlike previous object detection methods that required analyzing image regions separately, YOLO processes an entire image in one step, directly predicting bounding boxes and class probabilities for all objects. This makes YOLO computationally efficient and ideal for real-time applications like our IPS. By incorporating YOLO's advanced capabilities into our IPS, we have developed a system that is not only fast but also highly accurate and scalable, making it a robust solution to the pressing challenges of modern urban parking management.

Old parking system methods may suffer from revenue leakage due to human faults in license plate entry or outdated technology. With our system, the accuracy of billing improves. This ensures all vehicles are billed accurately, preventing lost revenue for parking operators.

Furthermore, our IPS enhances user convenience by integrating QR code payment at exit, eliminating the need for traditional payment terminals and reducing wait times [11]. Through extensive simulations and real-world deployment, our research demonstrates the efficacy of the IPS in reducing congestion, increasing revenue, and improving user satisfaction. This innovative system offers a comprehensive solution to modern parking challenges, optimizing space utilization and enhancing the overall parking experience for users and operators alike. Unlike the previous object detection methods that analyze image regions separately, YOLO takes a single image input and directly predicts bounding boxes and class probabilities for objects within the image in one go. This makes YOLO computationally efficient and ideal for real-time applications like our IPS.

**Table 1.** Comparison of parking systems in literature

| Ref. | Technology | Key Features | Main Contributions |
|---|---|---|---|
| [12] | Deep learning-based object detection | Detection of vehicle, license plate, and disability badges | 'Shine' system for managing accessible parking spaces (mAP: 92.16%). |
| [13] | YOLO v5 deep learning | Vehicle detection instead of parking slot classification | 99.5% accuracy, 45 FPS real-time performance on PKLot dataset. |
| [14] | ResNet34 deep classifier | APSD-OC | 2-step approach for high accuracy in parking slot occupancy classification. |
| [15] | mAlexNet, CNRPark + Ext dataset | Parking occupancy detection with IP Camera | 93.15% classification rate, 0.5s processing per space. |
| [16] | YOLOv2 target detection algorithm | Vehicle and parking space contour detection | 99.1% training accuracy using contour detection. |
| [17] | YOLO v5, Neural Networks | Real-time vehicle video detection | PIS for car, van, and truck detection. |
| [18] | LoRaWAN, AI-based predictors | IoT-based smart parking service in Santander | Enhances parking sensor readings with AI-based predictors. |
| [19] | IoT, Arduino UNO, Sensors | Smart parking model using IoT | FCFS scheduling model for parking slot allocation. |
| [20] | IoT framework, Mobile App | Intelligent Parking System (IPS) | Real-time data collection and mobile app integration. |
| [21] | Image Processing, Raspberry Pi | Smart Parking System with autonomous operations | Autonomous gate operation, real-time space management. |

## 2. LITERATURE REVIEW

Recent advancements in smart parking systems have leveraged various cutting-edge technologies, including deep learning, IoT, and blockchain, to enhance functionality and efficiency. Table 1 compares different smart parking methodologies in the literature. Various IoT-based solutions have been explored in the literature to improve smart parking systems. In the study [19], an IoT model with Arduino UNO and sensors implemented a First-Come-First-Serve scheduling model for parking slot allocation, while Aditya et al. [20] integrated IoT with a mobile app for real-time data collection and intelligent parking management. An image processing-based system in the study [21] utilized Raspberry Pi for autonomous gate operations and real-time space management. Blockchain technology has also been integrated into parking systems to secure service data, as shown in the research of Kumar et al. [22], where the Sawtooth blockchain tool was used for role-based access control. In the study [12], the SAMPARK protocol applied lightweight cryptographic primitives for secure communication in parking management. Additionally, Floris et al. [3] developed a Social IoT system with magnetometer sensors for scalable and interoperable parking services, and Jabbar et al. [4] introduced an IoT-SPMS-LoRaWAN model with extended-range sensing nodes.

## 3. METHODOLOGY

Figure 1 demonstrates the System architecture of the Intelligent Parking System. Modules of the Intelligent Parking System mainly consists of three modules.

### 3.1 License plate recognition module

This module starts with a camera with a resolution capturing the vehicle license plate at the entry point. The camera ensures an optimal and high-resolution image, precisely capturing key details for image processing. Image Acquisition and Preprocessing: the captured image undergoes a series of preprocessing steps to enhance image quality and clarity for text extraction. The binarization technique transforms the image into binary format, distinguishing between elements and background noise. A noise removal algorithm ensures the quality of captured images is free from distortions. YOLO processing, You Only Look Once object detection technology, the algorithm analyzes the captured image to identify and localize the license plate. YOLO efficiently detects the license plate bounded by environmental conditions, lighting variations, and vehicle orientations, ensuring robust performance and accuracy. Character Recognition employs OCR algorithms, analyzes detected license plates, and extracts alphanumeric characters accurately and quickly. Character Segmentation: through complicated pattern recognition and machine learning techniques, the system precisely deciphers the characters, conquering varying font styles, sizes, and plate angles. Database Management, the extracted text of the license plate, and the alphanumeric characters are directly inserted into the database with the user's timestamp and chosen block details. This process eliminates the manual work of database entries and monitors the in-time and out-time of the vehicle.

### 3.2 User's entry in parking lot module

Upon entry of a user into the premises of the parking area, the initial process executed is LPR, in which the license plate is detected, and the license number is extracted. Then, the user is given an option to select the block. Users will get three attempts to choose the right block where the user can park the vehicle. At every attempt, a new block is given to choose. If the user denies all three choices the system gives, the system chooses the block for the user, and block allocation is done. Based on the block allocated, the database entry is done using the timestamp. Block occupied is displayed on the display screen, along with the rest of the blocks in the parking area.

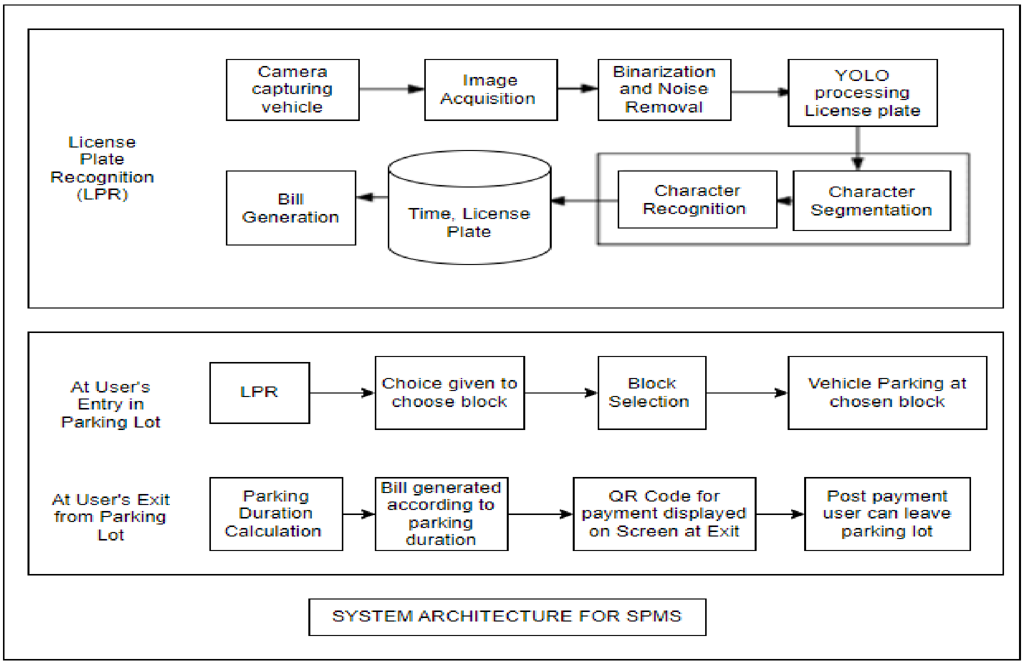


**Figure 1.** System architecture

### 3.3 User's entry in parking lot module

A dynamic QR code is displayed on the screen at the exit point. The parking fee is generated according to parking duration. The time is calculated between the entry and exit timestamp, and based on that duration, the fee is calculated on cost per hour. The QR code eases swift and contactless payment, eliminating the manual work of cash collection here. The system authorizes users to exit the parking area after payment. Using an efficient processing algorithm, the system speeds the authorization process, minimizing wait times and optimizing traffic flow within the parking area. Overall, by prioritizing operational efficiency and user ease in the parking area, the system enhances the effectiveness of parking management, simplifies the parking process, and streamlines entries and exits for all users.

### 3.4 Data collection

The dataset for training and testing the YOLOv5 model consists of 3500 images captured under varying lighting conditions, including diverse license plate formats from different states of countries. The dataset was divided into 70% for training and 30% for testing to ensure robust model evaluation. The YOLOv5 medium version was employed in terms of architecture due to its balance between speed and accuracy. The model was trained using the Adam optimizer with a learning rate 0.001 and a batch size 16. Modifications were made to the base architecture by adding additional convolutional layers to improve small object detection, which is critical for accurately identifying license plates.

### 3.5 YOLO architecture

Figure 2 demonstrates how YOLO [22] architecture works. It typically consists of several key components, mainly Convolutional layers, Residual Connections, Max Pooling, Concatenation layers, sampling layers, and final layers [23]. Integrating these components into the YOLO architecture improves efficient and accurate object detection in real-time applications. Convolutional layers: the first convolutional layer processes the input image, mostly $416 \times 416 \times 3$, with three color channels (red, green, blue). This layer applies 32 filters, and each generates feature maps. The size of each filter is $3 \times 3$. The second convolutional layer works on the previous layer's output ($416 \times 416 \times 32$). Utilizes 64 filters of $3 \times 3$ size and generates new feature maps. The dimensions are reduced to $208 \times 208 \times 64$ with max pooling.

To reduce vanishing gradients, residuals are used after convolutional layers. It adds the input of a layer to its output, which aids in gradient flow during training. Max pooling is done to downsample feature maps, reducing dimensionality and enhancing computational efficiency. Concatenation layers merge feature maps from different network parts for improved object detection. Up-sampling layers increase the resolution of feature maps. Existing feature map values are filled in for higher-resolution representations in this process. To reduce computational costs, the 1 × 1 convolutional layer reduce the number of channels in feature maps before passing them to the next layers. The final layers are responsible for object classification and bounding box regression. These layers predict the class probabilities and bounding box coordinates.

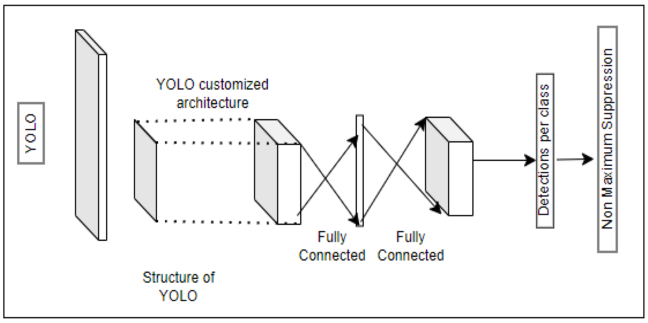


**Figure 2.** YOLO Architecture

### 3.6 License plate recognition module (LPR)

The system captures an image of the vehicle's license plates using the camera. The grayscale conversion, noise reduction, and image resizing are done in the pre-processing step. the captured RGB image converted to grayscale, techniques such as filtering applied to remove noise, and image resizing smoothens processing by the convolutional neural network. After the license plate is detected, individual characters are segmented from the license plate region. An Optical Character Recognition engine is applied to segmented characters converting them to alphanumeric code. The final output of the system is an accurately recognized license plate number.

### 3.7 YOLO and LPR integration

The YOLOv5 model detects license plates in real-time, and once detected, the plates are passed through an Optical Character Recognition (OCR) module for text extraction. The extracted text is then cross-referenced with a pre-existing database for vehicle identification. If the license plate matches an entry, the system automatically grants or denies access based on the user's parking status. In cases of entry, the time of arrival is logged, and upon exit, the duration of stay and parking fee are calculated. This entire process is automated to minimize manual intervention.

Figure 3 demonstrates the use case diagram of the Intelligent Parking System. The system has two actors the Admin and the User. The admin holds privileges for system configuration and management. Action 'Enter Parking Lot' outlines the complete entry procedure of the user which involves selecting the desired block for parking and parking vehicles in the parking lot. The 'Exit Parking Lot' outlines the complete exit procedure which involves Scanning a dynamic QR code for parking fee payment and exiting the parking lot.

### 3.8 Workflow

Figure 4 shows the workflow of our proposed Intelligent Parking System (IPS). It employs license plate recognition to guarantee effective parking. The license plate of the car is captured by the system once it is inside. Users may select a parking spot in the parking lot, depending on the particular system. The system then calculates the parking time and modifies the data in the database. When the vehicle leaves the parking lot, a receipt is produced and the payment QR code is shown. When the payment is finished by scanning the QR code, the car eventually leaves the parking lot. By eliminating the need for human permit entry, this automated solution simplifies the parking process for managers and vehicle owners.

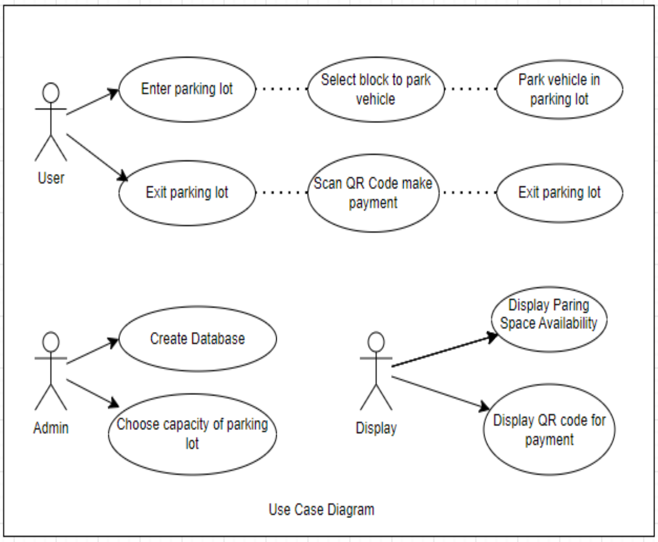


**Figure 3.** Use case diagram

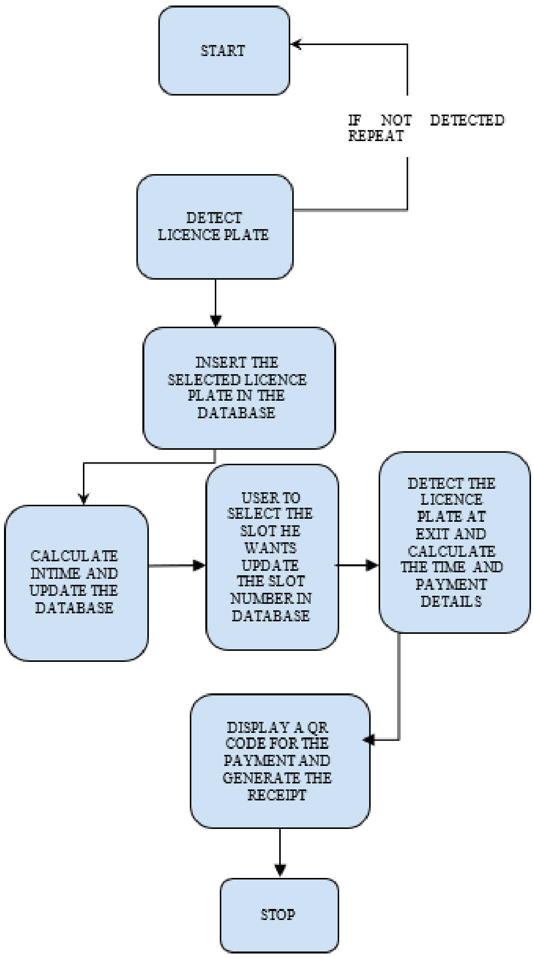


**Figure 4.** Workflow of intelligent parking system

## 4. RESULT AND ANALYSIS

• Case 1: Testing the YOLO model based on the character recognition rate. This can be calculated by comparing the dataset's truth values for license plates.

• Case 2: Comparing the performance of the YOLO-based character recognition against Tesseract-OCR to check if the new method learns better than the open-source character recognition software. character recognition rate will be used to measure the performance of these models.

• Case 3: Testing how well the YOLO character recognition works on a dataset with oblique license plates and how better the model performs.

### 4.1 Simulation setup

• Setup window for a vehicle parking system: The setup screen allows the admin to enter information such as the database name, username, password, and the number of two-wheeler and four-wheeler spaces.

• Authentication window for admin: The image depicts a secure login screen with username and password fields for verification.

• Parking slot selection: Users can slot available in a parking lot and park accordingly. Figure 5 demonstrates the Home window for a vehicle parking system. The home window shows slots in the parking lot. It shows which slots are occupied and which are not. The green slot shows the available slot, and the red slot shows the occupied slot.

Figure 6 demonstrates the Add Vehicle window, and Figure 7 demonstrates the Exit window. In the Add Vehicle window, an image of a car is selected, and using YOLO, the License plate number is extracted and added to the database. The Exit window displays current vehicles parked in the parking area.

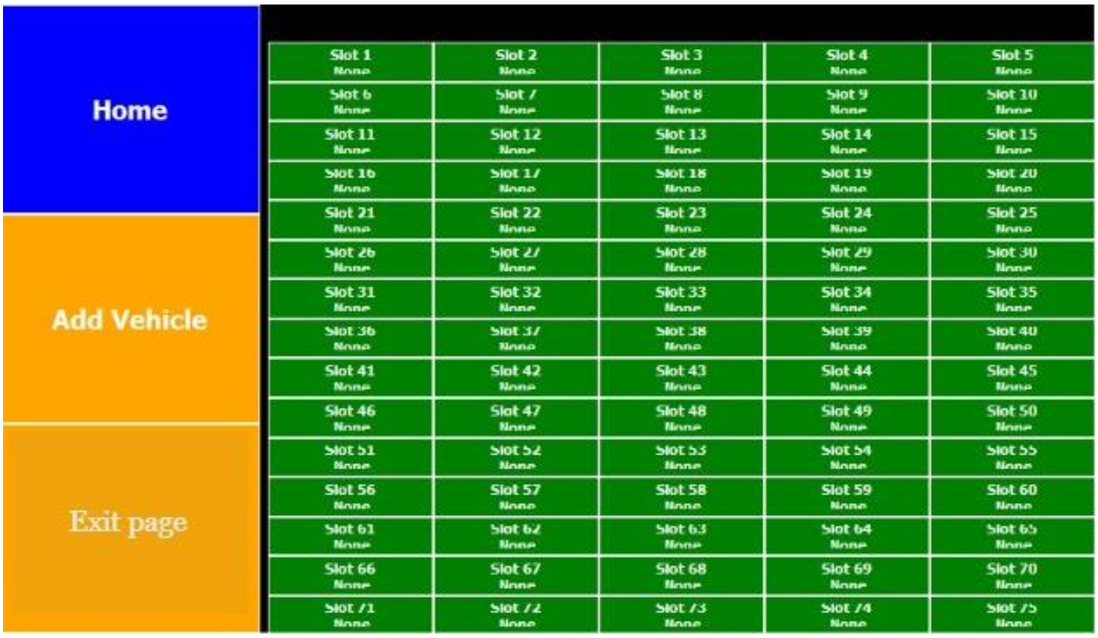


**Figure 5.** Workflow of intelligent parking system


**Figure 6.** Add vehicle to database using YOLO

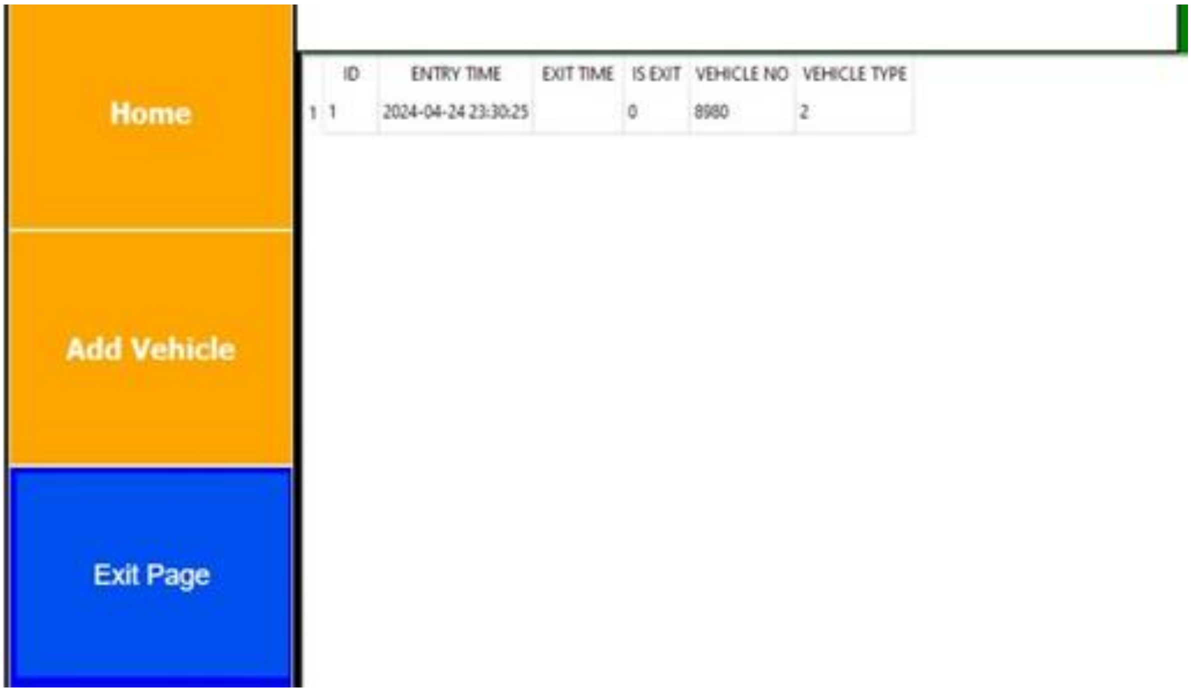


**Figure 7.** Exit window

### 4.2 Real-world deployment

• Compliance comparison with traditional systems: IPS outperformed traditional systems' effectiveness, efficiency, and user experience. Real-time processing using the YOLO model resulted in smoother operations and reduced administrative workload.

• User feedback and satisfaction: Feedback from users interacting with IPS was overwhelmingly positive. Automatic license plate recognition and a QR payment system were appreciated for a hassle-free parking experience.

•Billing accuracy improvement: IPS significantly improved billing accuracy compared to traditional systems. Reduction in billing errors and profit leakage due to automatic license plate recognition and real-time processing.

### 4.3 Evaluation metrics

•Accuracy: The automatic License Plate Recognition (LPR) system achieved a high accuracy of 97.11% (without considering spaces) and 91.91% (considering spaces).

•Recall: IPS demonstrated a recall rate of 97.25% (without considering spaces) and 95.4% (considering spaces), indicating effectiveness in identifying license plate numbers accurately.

## 5. LIMITATIONS AND FUTURE WORK

One of the primary advantages of the proposed LPR system is its scalability. The system can be deployed across multiple parking facilities and scaled to handle thousands of vehicles daily without significant changes to the architecture. The system's generalizability was tested by training it on datasets from different regions, demonstrating its potential to adapt to various formats and environmental conditions.

While the IPS has demonstrated promising results in simulations and real-world deployments, limitations exist. One limitation is the system's reliance on high-quality cameras and stable internet connections for optimal performance. The system's accuracy may decrease in real-world environments with variable lighting conditions and heavy traffic. Additionally, integrating the IPS with other smart city systems, such as traffic management or electric vehicle charging stations, presents challenges that need further exploration.

Future research could address these challenges and improve the system's resilience in diverse environments. User acceptance studies could also be conducted to gauge how the public interacts with and perceives this automated system.

## 6. CONCLUSIONS

The Intelligent Parking System (IPS) presented in this research demonstrates a significant improvement over traditional parking methods by utilizing real-time automatic License Plate Recognition (LPR) and YOLO-based object detection. Our system effectively streamlines the parking process, reduces human error, and simplifies infrastructure requirements by eliminating sensors and automating payment via QR codes. Real-world deployments have confirmed the system's ability to enhance operational efficiency, increase billing accuracy, and provide a seamless user experience. While the initial cost and reliance on advanced technology pose challenges, the overall benefits of reduced congestion, improved revenue management, and optimized space utilization make IPS a robust solution for modern urban parking needs. The IPS offers practical implications for urban environments, contributing to smarter and more efficient parking management systems.

## REFERENCES

[1] Ibrahim, M., Lee, Y., Kahng, H.K., Kim, S., Kim, D.H. (2022). Blockchain-based parking sharing service for smart city development. Computers and Electrical

Engineering, 103: 108267. https://doi.org/10.1016/j.compeleceng.2022.108267
[2] Limbasiya, T., Sahay, S.K., Das, D. (2022). Sampark: Secure and lightweight communication protocols for smart parking management. Journal of Information Security and Applications, 71: 103381. https://doi.org/10.1016/j.jisa.2022.103381
[3] Floris, A., Porcu, S., Atzori, L., Girau, R. (2022). A Social IoT-based platform for the deployment of a smart parking solution. Computer Networks, 205: 108756. https://doi.org/10.1016/j.comnet.2021.108756
[4] Jabbar, W.A., Tiew, L.Y., Shah, N.Y.A. (2024). Internet of things enabled parking management system using long range wide area network for smart city. Internet of Things and Cyber-Physical Systems, 4: 82-98. https://doi.org/10.1016/j.iotcps.2023.09.001
[5] Ma, X., Xue, H. (2020). Intelligent smart city parking facility layout optimization based on intelligent IoT analysis. Computer Communications, 153: 145-151. https://doi.org/10.1016/j.comcom.2020.01.055
[6] Dodia, A., Kumar, S., Rani, R., Pippal, S.K., Meduri, P. (2023). EVATL: A novel framework for emergency vehicle communication with adaptive traffic lights for smart cities. IET Smart Cities, 5(4): 254-268. https://doi.org/10.1049/smc2.12068
[7] Saharan, S., Kumar, N., Bawa, S. (2020). An efficient smart parking pricing system for smart city environment: A machine-learning based approach. Future Generation Computer Systems, 106: 622-640. https://doi.org/10.1016/j.future.2020.01.031
[8] Vlahogianni, E.I., Kepaptsoglou, K., Tsetsos, V., Karlaftis, M.G. (2016). A real-time parking prediction system for smart cities. Journal of Intelligent Transportation Systems, 20(2): 192-204. https://doi.org/10.1080/15472450.2015.1037955
[9] Said, A.M., Kamal, A.E., Afifi, H. (2021). An intelligent parking sharing system for green and smart cities based IoT. Computer Communications, 172: 10-18. https://doi.org/10.1016/j.comcom.2021.02.017
[10] Kim, O.T.T., Tran, N.H., Pham, C., LeAnh, T., Thai, M.T., Hong, C.S. (2019). Parking assignment: Minimizing parking expenses and balancing parking demand among multiple parking lots. IEEE Transactions on Automation Science and Engineering, 17(3): 1320-1331. https://doi.org/10.1109/TASE.2019.2948200
[11] Turki, M., Dammak, B., Alshahrani, A. (2024). PufParkChain: Secure and smart parking based on PUF authentication and lightweight blockchain. IEEE Access, 12: 65754-65767. https://doi.org/10.1109/ACCESS.2024.3398784
[12] Neupane, D., Bhattarai, A., Aryal, S., Bouadjenek, M.R., Seok, U., Seok, J. (2024). Shine: A deep learning-based accessible parking management system. Expert Systems with Applications, 238: 122205. https://doi.org/10.1016/j.eswa.2023.122205
[13] Rafique, S., Gul, S., Jan, K., Khan, G.M. (2023). Optimized real-time parking management framework using deep learning. Expert Systems with Applications, 220: 119686. https://doi.org/10.1016/j.eswa.2023.119686
[14] Grbić, R., Koch, B. (2023). Automatic vision-based parking slot detection and occupancy classification. Expert Systems with Applications, 225: 120147. https://doi.org/10.1016/j.eswa.2023.120147
[15] Farley, A., Ham, H. (2021). Real time IP camera parking occupancy detection using deep learning. Procedia Computer Science, 179: 606-614. https://doi.org/10.1016/j.procs.2021.01.046
[16] Zhou, H.B., Zhao, Y.M., Xiang, W. (2022). Method for judging parking status based on yolov2 target detection algorithm. Procedia Computer Science, 199: 1355-1362. https://doi.org/10.1016/j.procs.2022.01.171
[17] Morgos, J., Vorcak, J., Hrudkay, K. (2023). Parking information system with artificial neural network. Transportation Research Procedia, 74: 624-631. https://doi.org/10.1016/j.trpro.2023.11.190
[18] Santana, J.R., Sotres, P., Pérez, J., Sánchez, L., Lanza, J., Muñoz, L. (2023). Assessing LoRaWAN radio propagation for smart parking service: An experimental study. Computer Networks, 235: 109962. https://doi.org/10.1016/j.comnet.2023.109962
[19] Veeramanickam, M.R.M., Venkatesh, B., Bewoor, L.A., Bhowte, Y.W., Moholkar, K., Bangare, J.L. (2022). IoT based smart parking model using Arduino UNO with FCFS priority scheduling. Measurement: Sensors, 24: 100524. https://doi.org/10.1016/j.measen.2022.100524
[20] Aditya, A., Anwarul, S., Tanwar, R., Koneru, S.K.V. (2023). An IoT assisted intelligent parking system (IPS) for smart cities. Procedia Computer Science, 218: 1045-1054. https://doi.org/10.1016/j.procs.2023.01.084
[21] Sudhakar, M.V., Reddy, A.A., Mounika, K., Kumar, M.S., Bharani, T. (2023). Development of smart parking management system. Materials Today: Proceedings, 80: 2794-2798. https://doi.org/10.1016/j.matpr.2021.07.040
[22] Kumar, S., Rani, R., Chaudhari, U. (2024). Real-time sign language detection: Empowering the disabled community. MethodsX, 102901. https://doi.org/10.1016/j.mex.2024.102901
[23] Dodia, A., Kumar, S. (2023). A comparison of YOLO based vehicle detection algorithms. In 2023 International Conference on Artificial Intelligence and Applications (ICAIA) Alliance Technology Conference (ATCON-1), Bangalore, India, pp. 1-6. https://doi.org/10.1109/ICAIA57370.2023.10169773