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Development of automatic number plate recognition with optical character recognition

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ABSTRACT

Automatic number plate recognition (ANPR) has become increasingly relevant for modern access control systems, particularly in smart campus environments where efficiency and security are essential. This study presents the development of an integrated ANPR-based vehicle access control system that combines optical character recognition (OCR), a cloud-based Supabase PostgreSQL database, and Arduino-based actuation with an automated barrier gate mechanism. The proposed system utilises an AI-enabled Milesight MS-C2962-RFLPC camera for real-time license plate detection, while a lightweight Flask-based backend manages verification and decision-making processes. Vehicle data are organised into whitelist and blacklist tables within the cloud database, enabling automated access decisions without manual intervention. An Arduino Uno is employed to interface with the barrier gate for physical actuation. Experimental validation using real-world vehicle entries shows that the system achieves an overall recognition accuracy of 91% under varying lighting conditions. The prototype demonstrates stable system integration, responsive operation, and practical applicability for smart campus deployment. The proposed approach highlights the feasibility of combining embedded intelligence with cloud-based decision-making for efficient and scalable access control.

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1. INTRODUCTION

The rapid growth of vehicle ownership has increased the demand for intelligent and automated entry control systems, particularly in restricted locations like university campuses, residential areas, and secure facilities. Manual vehicle verification methods rely heavily on human monitoring, making them inefficient, error-prone, and unnecessary for high-traffic situations. As a result, automatic number plate recognition (ANPR) systems have evolved as a dependable technical option for real-time vehicle detection and surveillance. ANPR systems utilise image processing techniques like Optical Character Recognition (OCR) to extract alphanumeric characters from vehicle license plates. Recent improvements in artificial intelligence and deep learning have substantially increased the durability of ANPR systems, allowing for consistent performance in difficult conditions such as low illumination, nighttime operation, glare, and a variety of plate formats. When integrated with cloud databases and access control methods, ANPR systems may operate autonomously with minimal human intervention. This paper describes the development of an ANPR-OCR-based vehicle access control system, which includes a Supabase PostgreSQL database, an Arduino microcontroller, and an automated barrier gate. The system was designed for smart campus deployment, with

only registered vehicles allowed access. The proposed solution improves campus security, decreases unauthorised parking, and organises digital records for monitoring and analysis. Previous research has shown that Automatic Number Plate Recognition (ANPR) systems are widely used in traffic monitoring, parking management, toll collecting, security enforcement, and other access control applications [1]–[4], since they can automatically identify vehicles without human involvement. A typical ANPR framework includes image acquisition, image preprocessing, license plate detection, character segmentation, and character recognition stages. Environmental factors such as lighting variation, weather impacts, and plate orientation have a significant impact on the operation of these systems, affecting image quality and recognition accuracy directly [5]–[9]. Optical Character Recognition (OCR) is an essential part of ANPR systems, with both traditional and deep learning-based techniques under investigation in the literature [10]–[12]. Traditional OCR engines, such as Tesseract and rule-based ANPR systems, rely primarily on handcrafted features and established rules, rendering them ineffective when dealing with non-standard plate formats and complicated backdrops. Recent research has shown the effectiveness of Optical Character Recognition (OCR) in improving license plate detection and character recognition accuracy, especially in tough situations such as noise, motion blur, and font modification [10], [12]–[15]. Along with recognition accuracy, database integration has been identified as an important feature of modern ANPR systems. Relational databases like PostgreSQL and cloud-based platforms like Supabase provide efficient storage, retrieval, and real-time verification of license plate records. Several experts highlight the requirement for secure database systems, real-time data synchronisation, and access control techniques to support large-scale and IoT-based ANPR deployments [16]. Finally, hardware integration with high-resolution ANPR cameras, microcontrollers, and barrier gate systems has been identified to improve system automation and operational efficiency [3], [4].

Despite the growing adoption of ANPR systems in access control applications, existing solutions often focus either on software-based recognition or hardware-level implementation, with limited integration of cloud-based real-time decision-making and end-to-end automation. Furthermore, many campus-based ANPR systems lack seamless coordination between detection, verification, and physical actuation layers [1], [17]–[25]. Therefore, this paper aims to develop an integrated ANPR-based access control system that combines embedded AI-powered recognition, cloud database verification, and automated gate control in a unified framework. Meanwhile, the main contributions of this paper are i) development of an end-to-end ANPR system integrating camera-level OCR, cloud-based Supabase database, and Arduino-based actuation, ii) implementation of real-time decision-making using database-level logic for efficient access control, and iii) validation of the system in a smart campus prototype with practical deployment considerations.

2. METHOD

The proposed ANPR-OCR-based access control system was developed to allow accurate vehicle detection, quick decision-making, and easy integration of software and hardware components. Figure 1 shows the entire system workflow, focused on the connections between the ANPR camera, image processing module, Supabase PostgreSQL database, Arduino controller, and barrier gate mechanism. The ANPR system architecture consists of three major operational layers: input, processing, and output. The input layer uses an ANPR camera to capture images of vehicle license plates. The processing layer handles image preprocessing, license plate detection, character segmentation, OCR recognition, and database verification. The output layer operates the barrier gate and displays the access status to users. This modular architecture promotes scalability and improves system maintenance.



Figure 1. The block diagram of ANPR systems was designed in three major functions

2.1. Image acquisition hardware

Image acquisition is the first and most important stage of the ANPR system. Milesight MS-C2962-RFLPC network bullet camera (Figure 2) was chosen as the primary image capture device for an ANPR-based access control system because of its advanced AI-powered licence plate recognition capabilities. The camera supports high frame rates of up to 90 fps, allowing for accurate capture of fast-moving vehicles with

little motion blur. Table 1 present the specification of Milesight MS-C2962-RFLPC network bullet camera. Milesight MS-C2962-RFLPC ANPR camera is strategically placed at the vehicle entry point to capture clear frontal images of approaching cars. The camera continuously monitors the entry lane, capturing images when motion is detected inside the defined detection zone [24]. The camera features infrared (IR) illumination and adaptive exposure management to ensure consistent performance in a variety of scenarios [3]. This allows for excellent images captured during nighttime operation, low-light conditions, and severe weather such as rain or fog. Along with the captured image, details such as timestamp, detection region, and vehicle direction are generated for logging and analysis, as shown in Figure 3. Embedded ANPR processing enables real-time plate detection and recognition at the camera level, resulting in reduced system latency. The IP66-rated design offers durability for outdoor use in Malaysian weather conditions. Moreover, compatibility with standard network protocols allows for easy integration with the cloud database, Arduino controller, and barrier gate mechanism.



Figure 2. Milesight megapixel motorised pro bullet network camera

Table 1. Specifications of Milesight MS-C2962-RFLPC camera

No.	Parameter	Specifications
1.	Resolution	2 MP
2.	Lens Type	Motorised Lens, 2.7 – 13.5 mm
3.	Frame rate	Up to 90 fps
4.	IR range	Up to 100 m
5.	Wide Dynamic Range (WDR)	140 dB
6.	License Pplate Recognition (LPR)	Advanced LPR with vehicle classification
7.	PoE	12 V DC
8.	Ideal applications	Medium-traffic / intelligent monitoring



Figure 3. Image acquisition

2.2. Image preprocessing and recognition

2.2.1. Preprocessing

Images frequently have noise due to inconsistent lighting, shadows, headlight flashes, or surrounding reflections. Therefore, image preprocessing is used to improve image quality and recognition accuracy. Greyscale conversion is used at the preprocessing step to reduce processing complexity, followed by noise reduction with smoothing filters [6]. Contrast enhancement techniques are used to highlight the boundaries between license plate characters and the background. Moreover, edge enhancement is used to highlight character contours, ensuring that the plate region can be easily identified from the surrounding environment. These preprocessing techniques considerably increase the durability of the plate detection and OCR processes.

2.2.2. License plate detection

The ANPR camera's inbuilt AI-based detection system features are applied to ensure the license plate detection process. The detection mechanism recognises rectangular sections with high contrast and typical plate size. To accurately locate the license plate within the image, features such as aspect ratio, colour distribution, and edge density are utilised. This approach allows the system to detect plates even when the vehicles are slightly misaligned or taken from various angles. Accurate plate detection is crucial, as any error at this stage can propagate to subsequent stages and impact overall recognition performance.

2.2.3. Character segmentation

Character segmentation is an important step in extracting individual alphanumeric characters from the cropped license plate image. Structural techniques like reducing and eroding are used to remove tiny errors and separate interconnected characters [5]–[7]. The character boundaries are then identified using contour analysis, which takes into consideration size, shape, and spacing constraints. Each segmented character is treated as a separate picture and given to the OCR module. Proper segmentation ensures that overlapping or touching characters do not reduce recognition accuracy. Figure 4 shows an example of a license plate extracted into character segmentation.

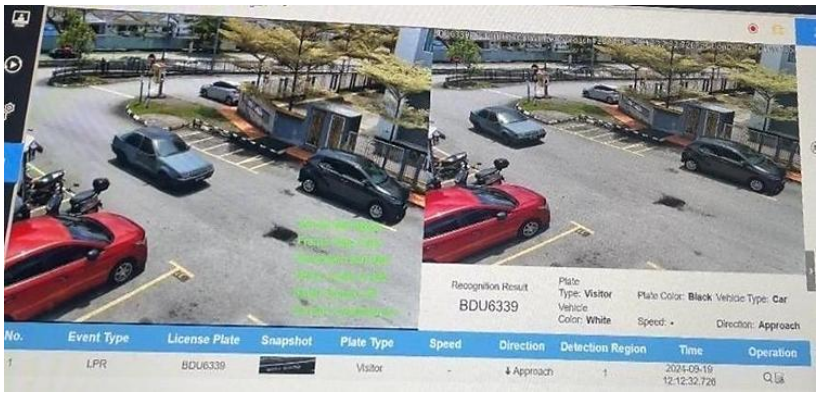


Figure 4. Example of license plate into character segmentation

2.2.4. Optical character recognition (OCR)

The OCR module turns segmented character images into machine-readable text. The OCR engine converts each character into its alphanumeric representation by analysing character layouts, line patterns, and pixel distributions. The recognised characters are then concatenated to create the entire number of the plate number. OCR accuracy is affected by font variety, plate cleanliness, and lighting conditions. The use of high-quality preprocessing and segmentation improves OCR performance in real-world applications [8]–[10].

2.3. Cloud database integration (Supabase)

The recognised plate number is transferred to a PostgreSQL-based Supabase cloud database. The database contains several tables, including registered vehicle listings (whitelist), blacklisted vehicles, and real-time detection records. Row level security (RLS) is used to prevent unauthorised access to important vehicle information. Database-level functions are utilised to determine whether a recognised plate is in the whitelist or blacklist tables, providing for secure and effective decision-making at the database layer.

2.4. Control and actuation module

The Arduino Uno microcontroller serves as a connection between the software system and the physical barrier gate. After an access decision is made, a control signal is transmitted to the Arduino by serial or network communication. The Arduino receives the signal and activates the proper output pins to control the barrier gate motor. This prototype hardware abstraction enables the software system to operate independently of each gate hardware implementation [4].

When the barrier gate motor receives an access approval signal, it raises the gate arm and allows vehicles to enter. A predefined delay is used to provide the vehicle enough time to pass safely before the gate automatically closes. In the event of access denied, the gate remains closed, and the driver must obtain manual verification from security staff. This automated process increases traffic flow while imposing strict access controls.

2.5. System workflow summary

Figure 5 illustrates the flowchart of the whole system workflow for the ANPR-based access control system, summarising its end-to-end functioning. From image capture to gate operation, all procedures are carried out automatically, assuring efficiency, precision, and dependability.

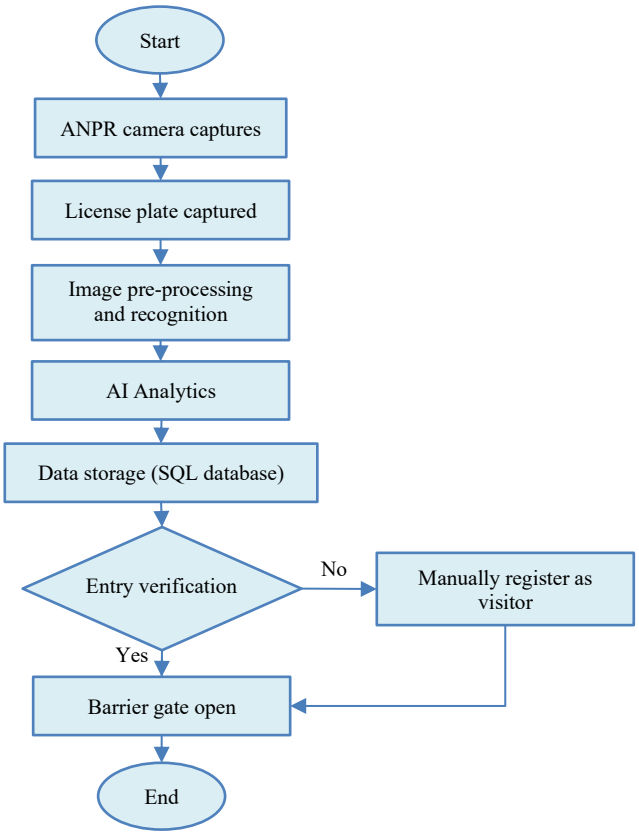


Figure 5. Flowchart whole system for the ANPR-based access control system

3. SOFTWARE INTEGRATION

The Supabase SQL Editor Dashboard, which was utilised in the development of the ANPR-based access control system. This interface provides for direct interaction with the PostgreSQL database via structured SQL queries. It was used to create, update, and manage database tables, including registered vehicles (whitelist), blacklisted vehicles, and LPR detection logs. Figure 6 shows the lpr_registered table. The SQL Editor also allowed the execution of database processes and triggers for real-time license plate verification. Using this dashboard, the system ensures structured data management, safe access control, and effective querying for ANPR operations.

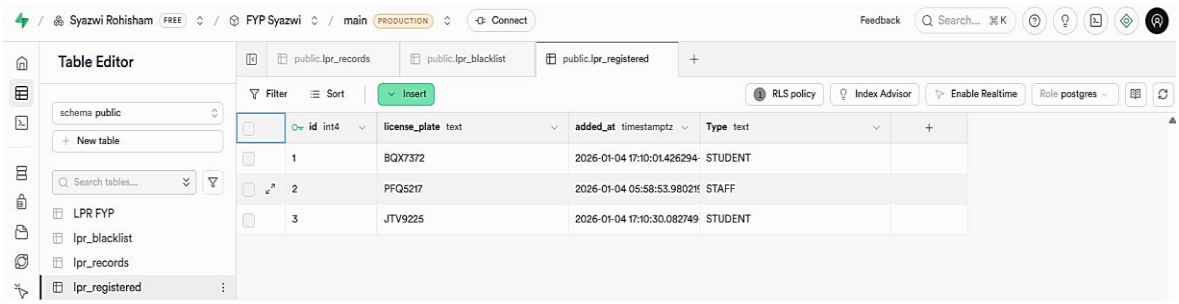


Figure 6. lpr_registered table

The database functions implemented in the Supabase PostgreSQL environment automate decision-making by evaluating if a detected license plate is listed in the whitelist or blacklist tables. When called by the database server, the function returns an access status signalling whether the barrier gate should open or remain closed. Implementing logic at the database level improves system performance, decreases backend processing load, and increases data security through controlled access mechanisms.

While the Visual Studio Code (VS Code) is used to develop and administer the ANPR backend system. The Python scripts that connect the ANPR camera, Supabase database, and Arduino controller were written using VS Code. The backend application verifies license plates in real time using Supabase API keys and database credentials and then logs results. This programming environment includes debugging tools, code management, and seamless integration with cloud services, making it suitable for developing complex ANPR systems. Then, the operation of the Python-based ANPR server with Windows PowerShell. The PowerShell interface shows runtime logs, such as license plate detection results, database verification status, and access control choices. This console output is crucial for monitoring system performance, resolving issues, and ensuring proper communication between software components. Running the backend server in PowerShell ensures that it runs smoothly during testing and deployment.

4. RESULTS AND DISCUSSION

The complete ANPR system prototype was developed, which includes the Milesight ANPR camera, backend processing unit, Supabase cloud database, Arduino Uno microcontroller, and automated barrier gate, as presented in Figure 7. This arrangement illustrates the entire operational workflow, encompassing vehicle detection, license plate recognition, access decisions, and physical gate management.

Figure 8 displays the license plate recognition results provided by the Milesight MS-C2962-RFLPC ANPR camera. Using its built-in AI-based ANPR and OCR capabilities, the camera effectively recognises and extracts alphanumeric characters from the vehicle's license plate. The recognised plate number is presented with the captured image, demonstrating accurate detection. This result indicates the capability of the chosen ANPR camera to offer high-accuracy recognition for automated access control applications.

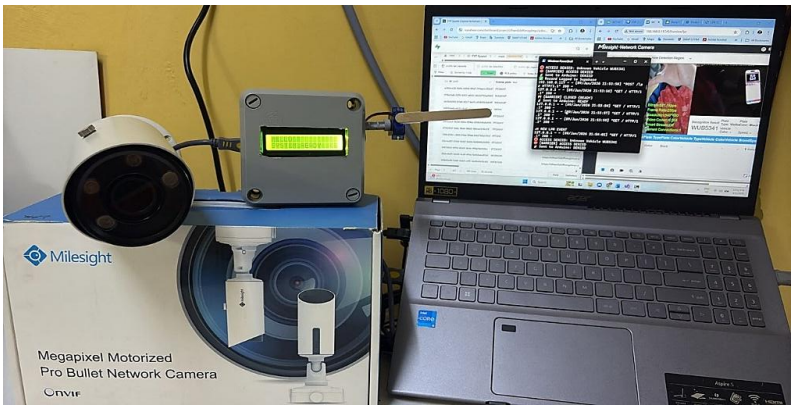


Figure 7. Complete ANPR system prototype

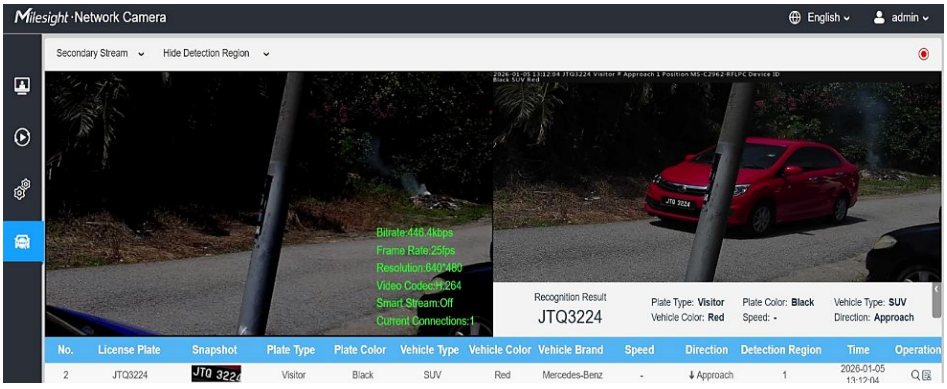


Figure 8. The result for MS-C2962-RFLPC

4.1. License plate recognition accuracy

The recognition accuracy of the developed ANPR-OCR system was evaluated using 100 vehicle entries captured by the Milesight MS-C2962-RFLPC ANPR camera in real-life situations. Testing occurred in daylight, low-light, and nighttime conditions using infrared illumination. Results showed that 91 out of 100 license plates were correctly detected, while 9 samples had incomplete or incorrect detection due to motion blur, glare, dirty plates, and non-standard font styles. Based on these findings, the system obtained an overall recognition accuracy of 91% for typical Malaysian plates. Recognition problems were most detected in scenarios involving broken plates, non-standard fonts, or extreme occlusion. The reported accuracy represents end-to-end system performance, including detection, recognition, and verification stages.

The obtained recognition accuracy of 91% is comparable to similar ANPR-based access control systems reported in the literature, where accuracy typically ranges between 85% and 95% depending on environmental conditions and system configuration [1], [9]. The achieved performance reflects the reliability of embedded camera-based OCR under real-world conditions. However, unlike purely software-based approaches, the proposed system emphasises integration efficiency and real-time deployment rather than algorithmic optimisation.

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4.2. LPR image management storage (Supabase)

Figure 9 depicts the Supabase storage management interface, which stores license plate photos captured by the ANPR system. The lpr-snapshots bucket was set up as a public cloud object storage repository for photos captured during vehicle detection events. The captured images were automatically uploaded with structured filenames that included the detected plate number, date, and timestamp. This naming system allowed for effective data organisation and retrieval. The user interface also showed metadata such as file type, size, upload time, and the latest changed date. A preview display enabled visual verification of collected images, ensuring accurate license plate detection.

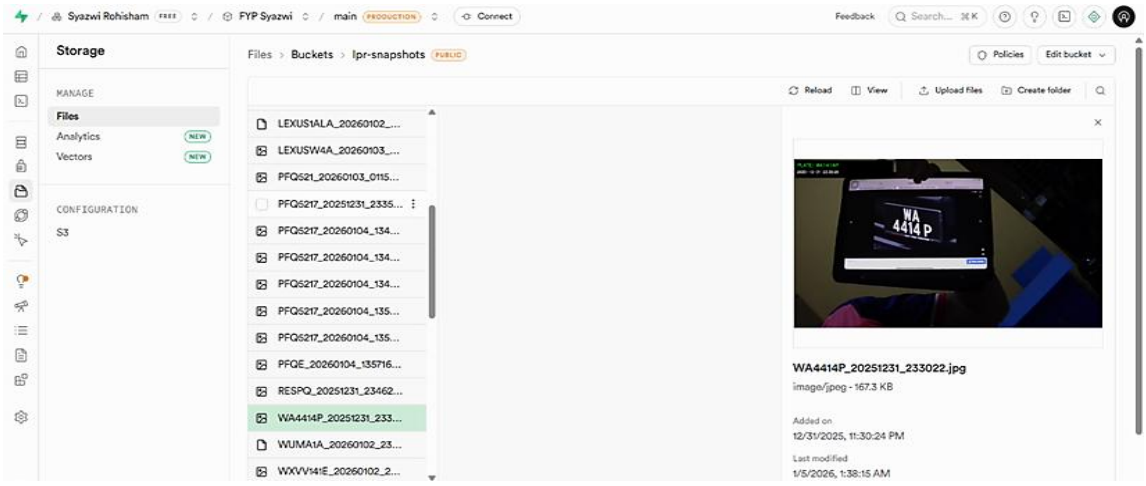


Figure 9. Supabase database storage

4.3. Processing time

A processing time analysis was performed to estimate the system's response time, including image collection, OCR time processing, database verification, and the delivery of barrier gate control signals. The processing time was calculated using timestamps from the Windows PowerShell console and Flask server logs during live system operation. The average processing time was determined by examining 100 consecutive vehicle detection events and can be summarised as shown in Table 2. Table 3 shows the summary of manual enforcement versus the operational efficiency of the proposed ANPR-OCE system.

Table 2. Average processing time

Processing Stage	Average Time (seconds)
Image captured by an ANPR camera	1.2
OCR character recognition	0.9
Database verification (Supabase)	0.3
Barrier gate response	0.1
Total Average Time	2.5

Table 3. Comparison of manual and proposed system

Feature	Manual	ANPR-OCR System
Average processing time	30 – 60 s	2.5 s
Manpower requirement	High	Minimal
Human error	High	Less
Operation Time	Limited	24 hours
Data logging	Manual/ incomplete	Automatic/ accurate

5. CONCLUSION

This paper presented the development of an ANPR-based access control system that integrates OCR, cloud-based verification, and automated barrier gate operation. The system was successfully implemented and tested under real-world conditions, demonstrating reliable performance and efficient operation.

While the system achieved a recognition accuracy of 91%, several limitations were identified, particularly under challenging conditions such as poor lighting and non-standard plate formats. Future improvements may focus on enhancing robustness using advanced deep learning techniques and addressing scalability and privacy concerns for larger deployments. Overall, the proposed system provides a practical and scalable solution for smart campus access control.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Abd Kadir Mahamad	✓	✓		✓			✓			✓	✓	✓	✓	✓
Maisara Othman					✓			✓		✓		✓		
Herdawatie Abdul Kadir					✓			✓		✓			✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author [Saon, S] upon reasonable request.

REFERENCES

[1] J. Tang, L. Wan, J. Schooling, P. Zhao, J. Chen, and S. Wei, "Automatic number plate recognition (ANPR) in smart cities: A systematic review on technological advancements and application cases," *Cities*, vol. 129, p. 103833, Oct. 2022, doi: 10.1016/j.cities.2022.103833.

[2] H. H. Imtiaz, P. Schaffer, P. Hesse, M. Kupper, and A. Bergmann, "Automatic number plate detection and recognition system for

small-sized number plates of category L-vehicles for remote emission sensing applications," *Sensors*, vol. 25, no. 11, p. 3499, May 2025, doi: 10.3390/s25113499.
[3] S. T. Patil, G. Gite, H. Hirkani, I. Bassan, and I. Raghvani, "Intelligent traffic monitoring system using infrared automatic number plate recognition (IR-ANPR)," in *2023 3rd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA)*, Dec. 2023, pp. 539–547. doi: 10.1109/ICIMIA60377.2023.10426538.
[4] C. J. Fernandez and R. R. Porle, "Raspberry Pi based ANPR for smart access," in *2021 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET)*, Sep. 2021, pp. 1–5. doi: 10.1109/IICAIET51634.2021.9573652.
[5] U. Salimah, V. Maharani, and R. Nursyanti, "Automatic license plate recognition using optical character recognition," *IOP Conference Series: Materials Science and Engineering*, vol. 1115, no. 1, p. 012023, Mar. 2021, doi: 10.1088/1757-899X/1115/1/012023.
[6] L. Jianyang, B. Junrong, L. Bingjin, F. Zhiang, and Z. Su, "The character recognition method based on OCR," in *2023 26th ACIS International Winter Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD-Winter)*, Jul. 2023, pp. 92–95. doi: 10.1109/SNPD-Winter57765.2023.10223979.
[7] L. Mingzhu, S. Yuxiu, and D. Yinan, "Research on optimization segmentation algorithm for Chinese/English mixed character image in OCR," in *2014 Fourth International Conference on Instrumentation and Measurement, Computer, Communication and Control*, Sep. 2014, pp. 764–769. doi: 10.1109/IMCCC.2014.162.
[8] R. Chaudhary, "License plate recognition system using computer vision and optical character recognition," *International Journal for Research in Applied Science and Engineering Technology*, vol. 13, no. 11, pp. 594–599, Nov. 2025, doi: 10.22214/ijraset.2025.75068.
[9] S. Parvin, L. J. Rozario, and M. E. Islam, "Vehicle number plate detection and recognition techniques: a review," *Advances in Science, Technology and Engineering Systems Journal*, vol. 6, no. 2, pp. 423–438, Mar. 2021, doi: 10.25046/aj060249.
[10] H. Moussaoui *et al.*, "Enhancing automated vehicle identification by integrating YOLO v8 and OCR techniques for high-precision license plate detection and recognition," *Scientific Reports*, vol. 14, no. 1, p. 14389, Jun. 2024, doi: 10.1038/s41598-024-65272-1.
[11] J. A. Jose, M. J. T. Dela Cruz, V. J. G. Garcia, M. H. C. Barrion, J. J. U. Keh, and T. S. Chu, "Development of a vision-based smart security system for vehicle entry monitoring in a subdivision," in *TENCON 2024 - 2024 IEEE Region 10 Conference (TENCON)*, Dec. 2024, pp. 1606–1610. doi: 10.1109/TENCON61640.2024.10902784.
[12] S. M N, S. Gopisetti, and C. M, "Smart ANPR: A checkpoint-based toll and parking management system using hybrid OCR and blockchain," in *2025 International Conference on Intelligent and Innovative Technologies in Computing, Electrical and Electronics (IITCEE)*, Jan. 2025, pp. 1–7. doi: 10.1109/IITCEE64140.2025.10915222.
[13] S. T. A. Ali, A. H. Usama, I. R. Khan, M. M. Khan, and A. Siddiq, "Mobile registration number plate recognition using artificial intelligence," in *2021 IEEE International Conference on Image Processing (ICIP)*, Sep. 2021, pp. 944–948. doi: 10.1109/ICIP42928.2021.9506699.
[14] A. George, E. J. Muttom, J. Joyan, N. Binoy, A. James, and R. Thomas, "ParkIt: An ANPR based automated parking registry using YOLO and EasyOCR," in *2025 2nd International Conference on Trends in Engineering Systems and Technologies (ICTEST)*, Apr. 2025, pp. 1–6. doi: 10.1109/ICTEST64710.2025.11042700.
[15] W. Weihong and T. Jiaoyang, "Research on license plate recognition algorithms based on deep learning in complex environment," *IEEE Access*, vol. 8, pp. 91661–91675, 2020, doi: 10.1109/ACCESS.2020.2994287.
[16] A. Ditta, M. M. Ahmed, T. Mazhar, T. Shahzad, Y. Alahmed, and H. Hamam, "Number plate recognition smart parking management system using IoT," *Measurement: Sensors*, vol. 37, p. 101409, Feb. 2025, doi: 10.1016/j.measen.2024.101409.
[17] P. Sharma, S. Gupta, P. Singh, K. Shejul, and D. Reddy, "Automatic number plate recognition and parking management," in *2022 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI)*, Jan. 2022, pp. 1–8. doi: 10.1109/ACCAI53970.2022.9752632.
[18] G. G, A. V Murthy, B. B, and Jagannath, "Dual security-check turnstile using ANPR technology," in *2023 7th International Conference on Design Innovation for 3 Cs Compute Communicate Control (ICDI3C)*, Nov. 2023, pp. 168–174. doi: 10.1109/ICDI3C61568.2023.00043.
[19] T. Mustafa and M. Karabatak, "Deep learning model for automatic number/license plate detection and recognition system in campus gates," in *2023 11th International Symposium on Digital Forensics and Security (ISDFS)*, May 2023, pp. 1–5. doi: 10.1109/ISDFS58141.2023.10131758.
[20] F. F. Petiwala, V. K. Shukla, V. P. Mishra, and S. Saini, "Smart parking system through automation in license plate recognition," in *2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)*, Sep. 2021, pp. 1–7. doi: 10.1109/ICRITO51393.2021.9596554.
[21] N. Min-Allah and S. Alrashed, "Smart campus—A sketch," *Sustainable Cities and Society*, vol. 59, p. 102231, Aug. 2020, doi: 10.1016/j.scs.2020.102231.
[22] K. Vijayalakshmi, M. Dhanamalar, V. A. Lepakshi, and S. Jamtsho, "Smart checkpoint management system for automatic number plate recognition in Bhutan vehicles using OCR technique," *SN Computer Science*, vol. 5, no. 5, p. 579, May 2024, doi: 10.1007/s42979-024-02905-2.
[23] J. C. Limon, K. Agustus Botangen, M. J. Malaca, R. Bermoza, and N. Vidania, "Utilizing automatic number plate recognition for an intelligent campus gate security system," in *2024 IEEE 6th Symposium on Computers & Informatics (ISCI)*, Aug. 2024, pp. 212–217. doi: 10.1109/ISCI62787.2024.10667725.
[24] R. Garg, R. Wason, P. Arora, and M. N. Hoda, "Robust advanced number plate recognition (ANPR) system from real-time video footage," in *2025 12th International Conference on Computing for Sustainable Global Development (INDIACom)*, Apr. 2025, pp. 1–4. doi: 10.23919/INDIACom66777.2025.11115864.
[25] E. Srividhya and T. C. S. R. Raju, "Automated number plate recognition system for secure zone monitoring," in *2025 7th International Conference on Intelligent Sustainable Systems (ICISS)*, Mar. 2025, pp. 833–839. doi: 10.1109/ICISS63372.2025.11076355.

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