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A Drone-Based Parking Enforcement System Using Ardu Pilot and Raspberry Pi 4

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Abstract

Accelerated urbanization has exacerbated parking-related challenges in urban centers, as inadequate enforcement leads to congestion, increased fuel use, and environmental deterioration. Conventional enforcement techniques, dependent on manual inspection, are labor-intensive, prone to errors, and lack scalability. This study introduces an automated drone-based parking enforcement system utilizing a 3DR Quadrotor equipped with the ArduPilot Navio2 autopilot and a Raspberry Pi 4 onboard computer. The platform utilizes high-resolution image sensors for real-time vehicle identification and license plate recognition (LPR). Flight dynamics and navigation are regulated by ArduPilot firmware, whilst LPR algorithms implemented on the Raspberry Pi analyze collected photos. Identified license plate information is delivered by secure Wi-Fi to a cloud-based Node-RED interface for analysis, visualization, and enforcement measures. The suggested system seeks to provide an effective and scalable solution that guarantees precise detection, dependable data transfer, and autonomous functionality in open-area parking lots. Experimental validation confirms its capability to surpass the constraints of traditional approaches, providing enhanced accuracy, efficiency, and adaptability for smart city applications.

1. Introduction

Urban growth has worsened parking problems in cities. Poor parking management causes traffic jams, wastes fuel, and harms the environment. Traditional parking enforcement relies on people, making it slow, costly, and prone to errors. New technologies like autonomous systems can improve parking enforcement. Drones (UAVs) are already used for tasks like surveillance and traffic control. Using drones for parking enforcement can provide a more flexible, efficient, and affordable way to monitor and manage parking areas.

2. Methodology

Traditional parking enforcement is slow, labor-heavy, and often inaccurate, especially in big cities. Manual checks and fixed cameras cannot monitor large areas in real time, which leads to illegal parking and wasted parking spaces. This project uses a drone system with high-resolution cameras and License Plate Recognition to spot vehicles and detect parking violations. The drone sends license plate data in real time to a cloud-based Node-RED system over Wi-Fi for analysis and action. By combining Navio2 and Raspberry Pi 4, this project creates an automated, scalable, and efficient system for enforcing parking rules in open areas with minimal human effort. The flowchart instructs the implementation of autonomous drones with license plate recognition. It begins with a selection of hardware components for the drone-like, 3DR quadrotor frame, brushless motors, ESCs, LiPo battery, GPS, IMU, camera, and sensors (e.g., LiDAR or ultrasonic) identified and procured. The selection ensures compatibility with the ArduPilot Navio2 and Raspberry Pi 4.

Fig. 1 shows an autonomous drone system that uses input components like Navio2, a GPS module, a camera, and an ESC to gather flight, location, and image data. A Raspberry Pi 4 processes this data and controls the outputs, which includes Node-RED for monitoring, a data center for storage, an RF transceiver for wireless communication, and a motor for drone movement. The entire system is powered by a lithium polymer battery, enabling the drone to fly, capture license plate images, detect parking violations, and send real-time data for smart parking enforcement with minimal human effort.

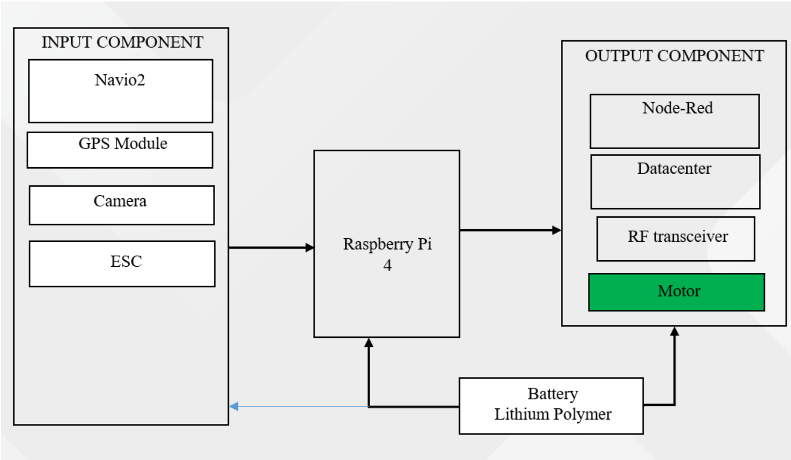

Fig. 1 *Block Diagram*

The flowchart in Fig. 2 shows the simple steps to build and test the drone parking enforcement system. First, the drone is assembled and the Navio2 is set up with the Raspberry Pi 4. Then, the sensors are calibrated and tested in the real environment. Next, YOLO is added for license plate recognition, and the system is tested for parking enforcement without using autonomous testing. If needed, the results are analyzed, and the system is recalibrated and fine-tuned until it works correctly. Finally, once validated, the drone is ready for smart parking enforcement.

3. Result and Discussion

3.1 Node-Red

Fig. 3 flow shows how the system captures and processes license plate images. It starts with a timestamp that triggers the flow, then a webcam takes a live picture. The image is processed to detect the license plate number, which is converted into a JSON format for easy data handling. Finally, the result is displayed in the debug panel so you can see the recognized plate number and related data, helping automate parking enforcement checks in real time.

3.2 Result from YOLOv8

Fig. 4 shows the confusion matrix to illustrate the model's accuracy post-validation. The X and Y axes denote the confidence percentage for predictions throughout both training and validation phases. The bold blue line indicates that the maximum F1 score is 0.42, occurring at a confidence level of 0.607. The equilibrium between accuracy and recall is optimal at this juncture.The Car class attains superior F1 scores compared to the Car License Plate class across the majority of confidence levels. The Car License Plate class has lower and less steady results due to the difficulty in detecting tiny or partially obscured plates. Conversely, the Car class exhibits greater consistency, enhancing the model's reliability in vehicle detection.The F1 curve for license plates has greater instability, indicating challenges in accurate detection. The maximum F1 score across all classes remains rather low, indicating potential for enhancement in both precision and recall, particularly in license plate identification.

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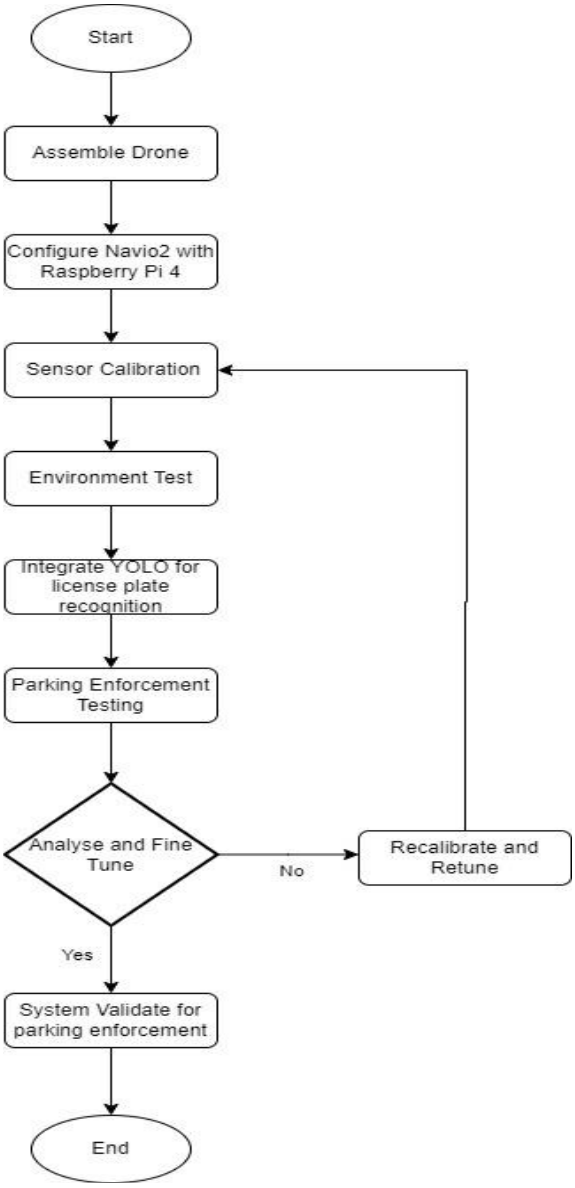

Fig. 2 *Flowchart of the system*

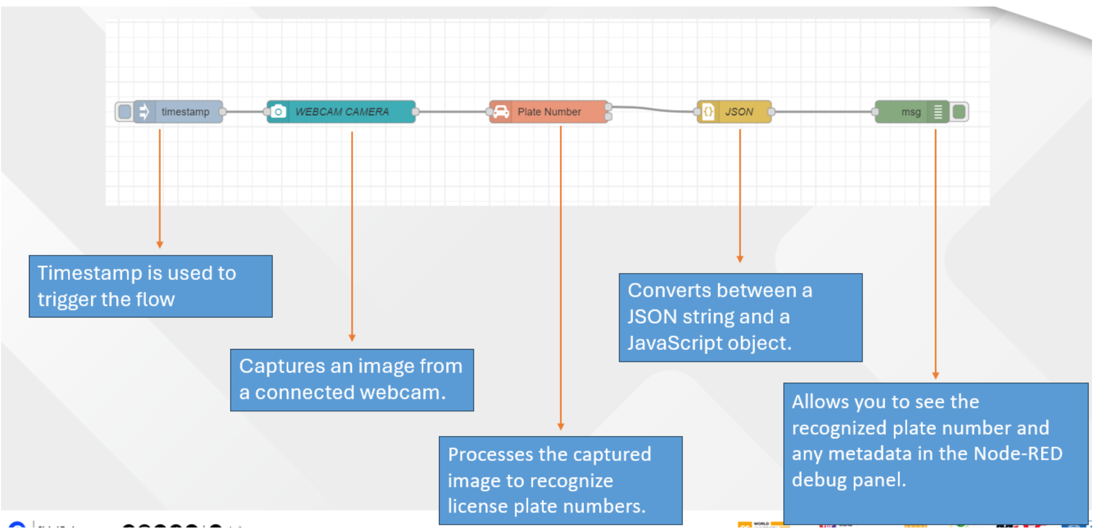

Fig. 3 *Node-Red*

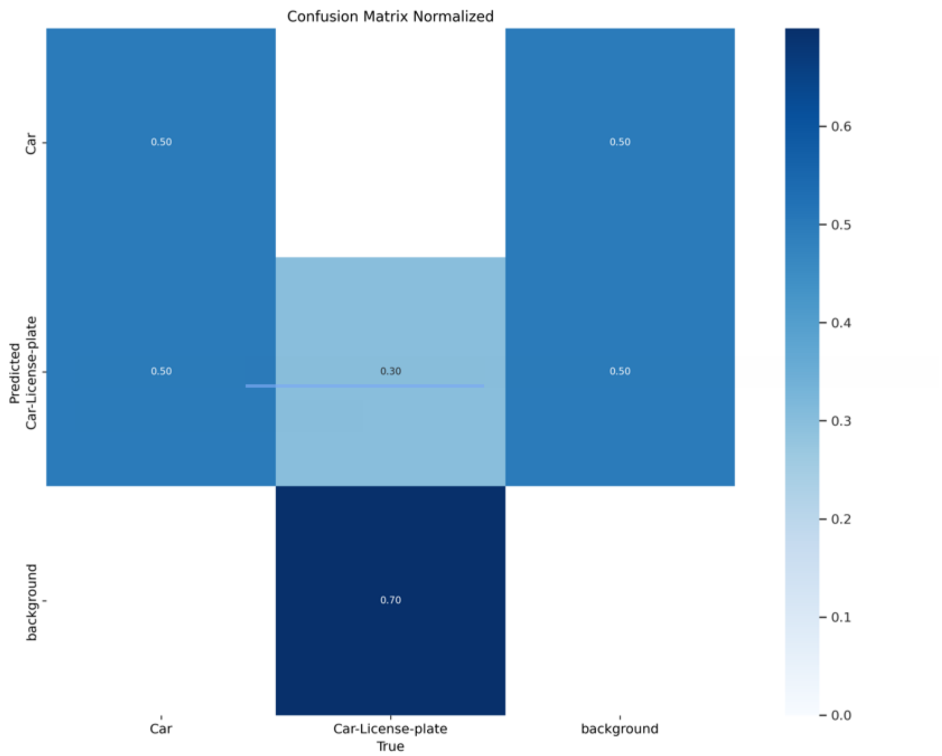

Fig. 4 *Confusion Matrix*

The illustration in Fig. 5 represents the F1–Confidence Curve, showing the model's stability between accuracy and recall across varying confidence levels. The dense blue line denotes all classes, with the peak F1 score of 0.42 at a confidence level of 0.607. Currently, the model excels in accurate detection while minimizing false positives. The Car class (light blue line) exhibits more stability and superior F1 scores compared to the Car License Plate class (orange line). License plate identification is compromised and inconsistent due to the tiny size of plates, potential blurriness, confusion, or challenging viewing angles. On the other hand, automobile detection is more dependable and uniform. The model effectively detects autos but has difficulties with license plates, indicating a requirement for enhanced training data or refined model architecture.

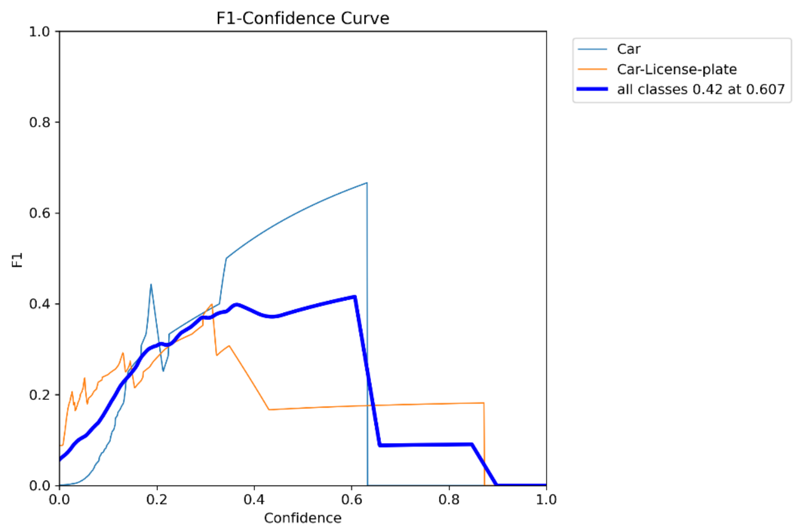

Fig. 5 *F1-Confidence Curve*

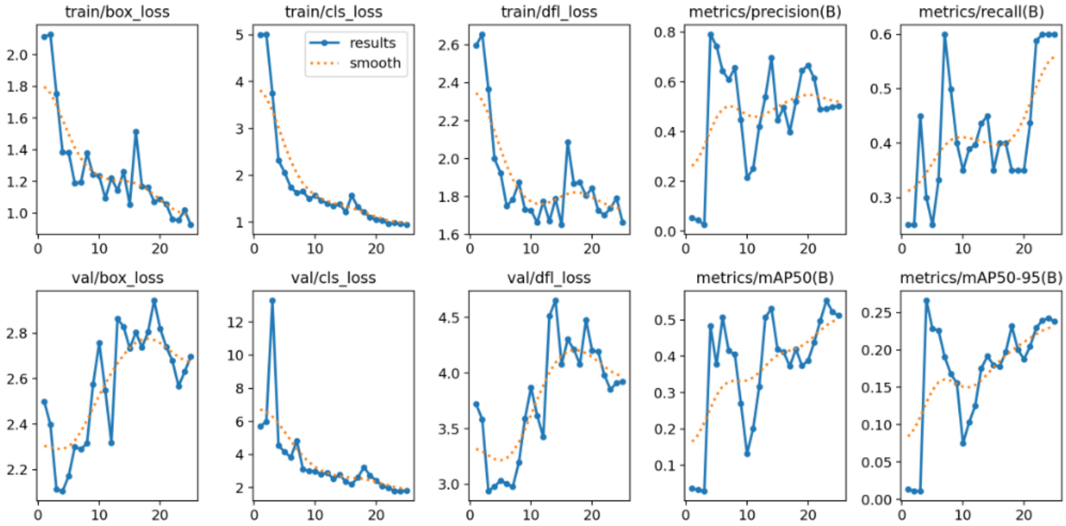

Fig. 6 *Parameter of YOLOv8 output model*

Fig. 6 displays many factors that represent values including training, validation, and metrics confidence scores. The three top parameters on the left denote the value of training parameters, allowing us to infer the confidence in the trends of these parameters. The training losses show a downward trend, signifying that the model is acquiring knowledge. Although validation losses decline, they exhibit greater volatility, indicating either overfitting or noise within the dataset.

Table 1 *Output testing YOLOv8*

Type of Index	Index 1	Index 2	Index 3	Index 4
Output from Image Testing				

Table 1 presents the confidence levels of validation pictures from the earlier training. The table concludes that the pretrained model can recognize the categories of the index with a high confidence level ranging from 0.5 to 0.9 and higher, indicating the model's accuracy in identifying those indices. The confidence level is lower than the anticipated result, ranging from 0.65 to 0.75.

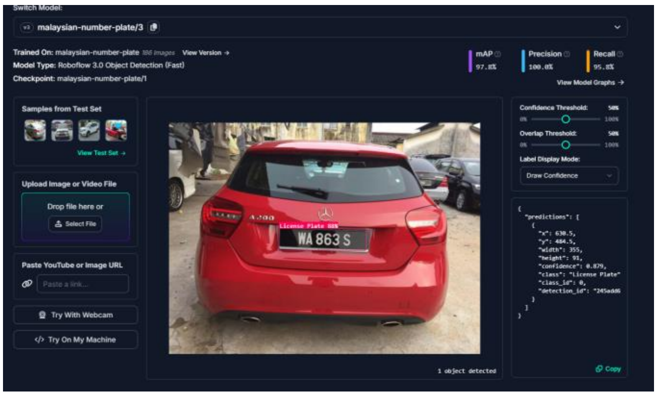

Fig. 7 *Result from Roboflow*

Fig. 7 depicts Roboflow shows the outcome of the Malaysian license plate detection system utilizing a trained object detection model. The technology can identify and outline the license plate “WA 863 S” on the red vehicle. The model was trained with the Roboflow Object Detection (Fast) methodology, achieving exceptional performance metrics, mean Average Precision (mAP) of 97.4%, precision of 99.6%, and recall of 98.8%. The technology can reliably recognize number plates and barely mistakes or overlooks a plate. The model utilizes a confidence threshold of 50%, so accepting only detections that exceed this criterion. The output data furthermore encompasses the plate's location within the picture (bounding box), which may be utilized for subsequent operations such as character recognition. This outcome demonstrates that the model is appropriate and dependable for applications in Electrical and Electronic Engineering, including smart parking, vehicle tracking, and traffic enforcement.

3.3 Testing and finding result

QGroundControl is a ground control station (GCS) software program utilized for the monitoring, configuration, and control of drones operating on autopilot systems such as ArduPilot or PX4. It offers a real-time interface for flight telemetry, mission planning, parameter adjustment, and sensor calibration. Operators may utilize the graphical dashboard to see drone information, including GPS position, altitude, battery voltage, and flying modes, as well as submit autonomous mission waypoints. QGroundControl facilitates the MAVLink communication protocol, guaranteeing dependable data transmission between the drone and the operator. It functions as the "control center" for drones, enabling users to establish missions, monitor flights, and effectively manage system performance.

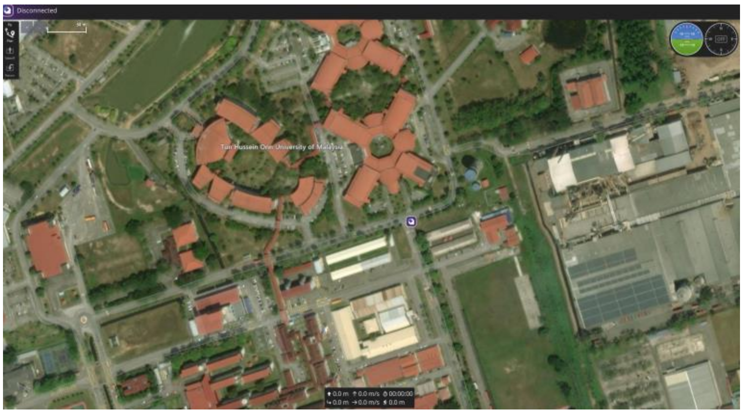

Fig. 8 *Qground control mapping*

Fig. 9 shows a live feed image from the webcam used in the drone system to capture clear images of parked vehicles. The camera takes pictures of cars and their license plates so the system can check for parking violations. This real-time image capture is an important part of the drone’s job in monitoring and enforcing parking rules accurately and automatically.

Fig. 9 *Result from Drone Camera*

Snaphot cloud stored all captured image and display all the outcomes of the license plate detection system evaluated on several automobiles utilizing a webcam as shown in Fig. 10. Each row presents the identified plate number, timestamp, camera source, and detection confidence level. The majority of detections exhibit high accuracy, with confidence values over 90%, including BMM 4469 (96%), KFX 4370 (100%), and CIM 1189 (99.9%), demonstrating the system's efficacy across many situations. Results as low as WLN 1559 (90.7%) are acceptable for acknowledgment. The system consistently produces dependable outputs with high precision, rendering it appropriate for applications such as parking enforcement, traffic surveillance, and vehicle administration.

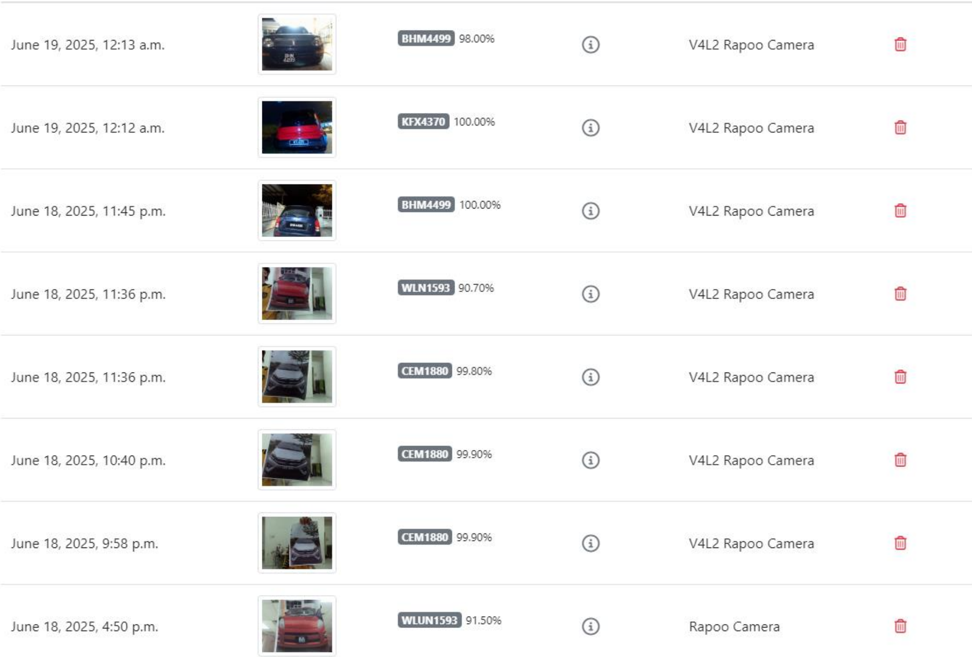

Fig. 10 *Result Snapshot Cloud*

Fig. 11 shows the debug menu of the Node-RED. This output from the drone's license plate recognition system, displays the details of a detected vehicle, including the processing time, the recognized plate number, the confidence scores, the vehicle type, and the image file information from the Rapoo Camera. This information confirms that the system successfully captures and processes parking data in real time, helping automate parking enforcement efficiently.

Fig. 11 *Debug menu from Node-Red*

As shown in Fig. 12, this prototype is a quadcopter drone using four brushless DC motors linked to electronic speed controllers (ESCs) for stable lift and maneuverability, with a central flight controller (such as ArduPilot or Pixhawk) serving as the processing unit for sensor data and stability maintenance. It is equipped with a mounted camera system and supporting electronics for purposes such as license plate identification or surveillance, while a GPS antenna guarantees precise navigation. The system operates on a Li-Po battery with integrated wiring for power and data transmission. The drone is constructed with a lightweight, sturdy chassis to reduce vibration and ensure stable flight, rendering it appropriate for autonomous functions like parking enforcement or aerial inspection.

Fig. 12 *Prototype Drone*

4. Conclusion

In conclusion, this project successfully demonstrates an autonomous drone-based parking enforcement system that combines Navio2, Raspberry Pi 4, YOLO license plate recognition, and real-time data transmission using Node-RED. By integrating high-resolution imaging, precise flight control, and smart detection algorithms, the drone can monitor parking areas efficiently with minimal human effort. The use of reliable components like the AIR 2216/KV880 motor, ESC, LiDAR sensor, GPS antenna, and real-time voltage monitoring ensures stable operation and accurate results. This prototype proves the feasibility of using drones for automated parking enforcement, offering a scalable and sustainable solution for smart city traffic management in the future.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception, design, data analysis and manuscript preparation:*** *Muhammad Hadi Syazwan; Mohamad Fauzi Zakaria. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] A. Javaheri et al., 'Evaluating Impact of Smart Parking Systems on Parking Violations', IEEE Access, pp. 1–1, 2024, doi: 10.1109/ACCESS.2024.3503513.

[2] C. L. K. Ye, H. S. Jo, and R. S. Jo, 'Development of UAV -based Automated Vehicle Recognition System for Parking Enforcement', in 2019 4th International Conference on Robotics and Automation Engineering (ICRAE), Nov. 2019, pp. 111–115. doi: 10.1109/ICRAE48301.2019.9043803.

[3] C. Smith, F. A. Zeudom, J. Grsossman, and S. Khorbotly, 'A Computer Vision-Based System to Study Parking Utilization', in 2024 IEEE International Conference on Electro Information Technology (eIT), May 2024, pp. 337–341. doi: 10.1109/eIT60633.2024.10609875.

[4] H. Fakhrurroja, D. Pramesti, A. R. Hidayatullah, A. A. Fashihullisan, H. Bangkit, and N. Ismail, 'Automated License Plate Detection and Recognition using YOLOv8 and OCR With Tello Drone Camera', in 2023

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International Conference on Computer, Control, Informatics and its Applications (IC3INA), Oct. 2023, pp. 206–211. doi: 10.1109/IC3INA60834.2023.10285750.
[5] 'Smart Selangor Parking – Smart Selangor'. Accessed: Jan. 14, 2025. [Online]. Available: https://www.smartselangor.com.my/services/smart-parking/
[6] A. Kujawski and M. Nürnberg, 'Analysis of the Potential Use of Unmanned Aerial Vehicles and Image Processing Methods to Support Road and Parking Space Management in Urban Transport', Sustainability, vol. 15, no. 4, p. 3285, Feb. 2023, doi: 10.3390/su15043285.
[7] P. Harrington, W. P. Ng, and R. Binns, 'Autonomous drone control within a Wi-Fi network', in 2020 12th International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP), Jul. 2020, pp. 1–6. doi: 10.1109/CSNDSP49049.2020.9249585.
[8] O. McAree, J. M. Aitken, and S. M. Veres, 'A model based design framework for safety verification of a semi-autonomous inspection drone', in 2016 UKACC 11th International Conference on Control (CONTROL), Aug. 2016, pp. 1–6. doi: 10.1109/CONTROL.2016.7737551.
[9] M. G. Rao, G. G, N. T. C, and A. B. Pradeep, 'Authentication and Parking of the Vehicle Using License Plate Detection and Recognition in the Campus', in 2022 International Conference on Artificial Intelligence and Data Engineering (AIDE), Dec. 2022, pp. 74–79. doi: 10.1109/AIDE57180.2022.10059957.
[10] C. R. De Cos, M. J. Fernandez, P. J. Sanchez-Cuevas, J. Á. Acosta, and A. Ollero, 'High-Level Modular Autopilot Solution for Fast Prototyping of Unmanned Aerial Systems', IEEE Access, vol. 8, pp. 223827–223836, 2020, doi: 10.1109/ACCESS.2020.3044098.