

Improvement on Road Management System: Artificial Intelligence Application based on Plate Number Detection System using YOLO Algorithm

Zeng Yukun & Azman Ab Malik*

School of Computer Sciences, Universiti Sains Malaysia, 11800 USM, Pulau Pinang

*Corresponding author: azman.abdul@usm.my

Received 24 September 2024, Received in revised form 3 May 2025

Accepted 3 June 2025, Available online 30 August 2025

ABSTRACT

Traffic jams is a typical urban problem caused by a variety of reasons such as high traffic volume, construction, roadwork, incidents, and accidents. With the development of urbanization, daily traffic has become a problem, especially in some key areas of heavy road or parking can cause serious traffic problems. There are many method has been suggest to reduce a traffic such as using public transport, carpooling, ridesharing, traffic management system, road infrastructure improvements, flexible work hours and promoting non motorized transport. One of the approach suggest is to improve a time consume by vehicle on the road. Abnormal pattern can be define by using plate number detection and the information will send to authorized organisation to alert or support for road management system. In this project, a system has been developed using Python and YOLO model to monitor a specified area with an external camera, identify vehicles within the area by recognize license plates. Based on the experiment conducted, 88.23% of number car plate has been indentified. The system aims to solve the problem of unauthorized road or parking by tracking the time or how long a vehicle stays in the monitored area. If a vehicle exceeds a predetermined time limit, the system triggers an alert to authorize people. The solution is designed to reduce traffic jam or parking area and ensure well-organized vehicle management in restricted areas.

Keywords: Traffic jam; number plate extraction; road management System; YOLO algorithm; Python; license plate recognition

INTRODUCTION

The centre of human concentration area can be identified based on sports venues, industries, raw materials, religious and places of study. India is expected to have a large human population by 2050. In books with tittle The Statesman's Yearbook 2024 by Macmillan in 2022 stated that population growth has been consistent from 1950, when India was ranked second with 376325000, rising to 1366418000 in 2019 and expected to reach 1639176000 by 2050.

In general, having too many people causes traffic congestion. The situation gets worse by unforeseen occurrences such as vehicle breakdowns, waiting for other passengers in a particular place, and the weather. Failure to control vehicles on important roads will result in traffic difficulties. As mentioned by Al-Ajarma et al. 2021, one of the five pillars of Islam is the Hajj, or trip to Mecca, which Muslims are required to perform. Millions of

Muslims congregate in the Saudi Arabian holy city of Makkah for the annual Islamic pilgrimage known as Hajj.

As mentioned by Gazzawe, Foziah and Marwan Albahar in 2024, in general, the number of people who attend the Hajj pilgrimage has increased throughout the years; as of right now, over 140,000 people from within the country and over 700,000 people from outside have attended. With 3 million pilgrims visiting Makkah on average every year, getting from Arafat to Muzdalifah has grown more difficult as a result of the growing number of participants.

Multiple movements of large numbers of people in a short period of time, as well as Hajj locations, can present serious transportation challenges, with fixed and limited road networks and bus capacity frequently insufficient in relation to demand, resulting in congestion and traffic jams and longer travel times. This is highlighted by Owaidah et al. (2023), transportation poses a major challenge for Hajj

authorities in charge of managing people. One of the most obvious instances is that pilgrims traveling from outside the area will mainly focus on their arrival in the first few days of the Hajj, and locations such as the surrounding hotels turn out to be their first stop on the route to the area. Because of the large number of people, it takes a long time for them to get off the buses and into the hotels, and the extended pausing of buses in these hubs can cause traffic delays.

There are many reasons of traffic congestion such as bad weather, rush hour, illegal parking, work zone, road environment, traffic accident and others factor. Despite the increasing expansion of car ownership in China's main cities, the true difficulty is the mismanagement of existing parking spaces rather than a lack of parking facilities. This increases traffic flow as people drive around looking for cheaper, or even free, on-street parking. As a result, on-street parking influences traffic congestion. Furthermore, a lack of parking management and enforcement causes bike lanes, sidewalks, and bus stops to become congested, and parking interferes with different kinds of mobility.

Based on these scenarios, to solve the traffic problems caused by overtime parking in specific areas, a monitoring system is needed for identifying and overtime flow on the road or in parking. To ensure smooth vehicle movement and avoid congestion, it becomes crucial to efficiently monitor traffic flow in urban contexts, whether it be on designated roadways, at intersections, or in specific regions. Many of the traffic control systems in use today can't provide precise, real-time tracking of traffic flow. Long-term can block traffic lanes, lower the capacity of the road, and cause major delays. It is crucial to respond to these situations quickly to minimize delays and preserve traffic safety. In order to properly handle such problems, current systems frequently lack the automatic alerting and real-time monitoring features that are required. The potential of AI in the road management system is being researched to address the severe traffic issues on the roads. So, developing a smart number plate for vehicles based on an overtime monitoring system using AI technology is one option to enhance road traffic.

The concept of "You Only Look Once" (YOLO) has become common in object detection. Redmon et al. in 2016 provided the first introduction of YOLO version. In recent years, researchers Zhao et al. 2019, Zou et al. 2019, Laroca et al. 2018, Tian et al. 2019, Jamtsho et al. 2021, Jamtsho et al. 2020, Han et al. 2018, Lin et al. 2018, Lu et al. 2018, Huang et al. 2018 and Gong et al. 2020 have released various YOLO versions, including YOLO V2, YOLO V3, YOLO V4, YOLO V5, and YOLO-LITE. The YOLO revolution demonstrates a different conceptual design and implementation. This study focuses on the creation of YOLO V5 and its applications.

These algorithms are fast since YOLO must load the image into the network to obtain the final detection result. Furthermore, YOLO can be used to detect time in by camera. It turns the challenge of target detection into a regression problem. However, the accuracy should be increased. To improve detection performance, YOLO makes use of a number of lower sampling layers and completed target attributes that the network has learnt. Two fully connected layers came after 24 convolution layers in the original YOLO design.

YOLO predicts numerous bounding boxes in each grid cell. These bounding boxes have the highest Intersection Over Union (IOU). Jamtsho et al. 2021 has included the selected ground truth, which is known as non-maxima suppression. While in its early stages, YOLO clearly has two drawbacks: inaccurate location and a less prosperous recall rate as compared to area advice. So, the improvement can be noticed in the YOLO V2, which is better and faster.

Standardizing the input of each later, accelerating convergence, removing the loss, and boosting mAP to its equivalent by 2%. YOLO has been improved throughout time in terms of high-resolution classifiers, fine features, multi-scale training, classification training, detection training, and other development elements. Table 1 shows version breakdowns by year.

	V2	V3	V4	V5	Total
2016	0	0	0	0	0
2017	5	0	0	0	0
2018	47	19	0	0	66
2019	48	210	0	0	258
2020	36	496	81	13	626
Total	136	725	81	13	955

Source: Jiang et al. (2022)

The first objective for this project is to develop a prototype of vision systems at transportation hubs or in certain specific areas to monitor the area conditions. This project used camera to monitors the crowded road or some special area and YOLO algorithm to recognize license plate. Benefit of using YOLO, detection are accurately detects and identifies vehicles, monitors traffic flow and enforces parking regulations in real time. It will improve the ability of traffic management authorities to manage heavy traffic areas and reduce parking violations, thereby improving overall traffic conditions.

By monitoring and managing parking in real-time, the system will reduce traffic congestion. This ensures smoother traffic flow, especially in high-traffic areas and during significant events. Second objective for this project is to develop road management system. When a vehicle

spends more than a threshold amount of time in the range, it will be flagged in the system, which allows the relevant personnel to react in a timely manner. Database will be used to record the traffic flow in the monitored area and keep a record of the vehicle availability on the road or specific area. The automatic timeout alert function allows an authorized person to manage the monitoring without having manual observation especially on the timeout situation of the vehicle. The intuitive user interface provides real-time data visualization, enabling traffic authorities and staff to monitor and manage road or overtime time taking on the parking violations area.

PREVIOUS STUDY

Advances in artificial intelligence have led to great developments in object detection in recent years, making it an important component and a popular subject for computer vision research. Nowadays, object detection is widely used in numerous areas of daily life. As an example, it is used to identify and detect cars, pedestrians, and other road objects in autonomous driving. In a research by Wang et al. 2023 object detection helps with activities like tumor detection and others significant area in medical such as diagnosis and treatment. It is also crucial in various industries including agriculture and skin treatment.

The You Only Look Once (YOLO) algorithm is a real-time target detection technique that separates the input image into a grid and estimates several bounding boxes for each grid cell, along with their confidence scores which include centre coordinates, width, height, and the likelihood of an object being present and the conditional probability that the grid cell will contain objects belonging to each category. In the end, the confidence score and category probability are multiplied to determine each bounding box's score. Overlapping boxes are then eliminated using the non-maximal value suppression technique, leaving only the box with the highest score as the final detection result. This allows for quick and effective target detection and classification as mentioned in the article by Rekha et al. in 2020.

In a research by Li et al. 2021 The Faster R-CNN is a region proposal based on target detection algorithm. Framework for Faster R-CNN It generates candidate target frames by introducing Region Proposal Network (RPN) and feeds these candidate frames into the subsequent target detection network for classification and regression. RPN extracts candidate frames on the feature map using a sliding window and performs binary classification either target or background and bounding box regression on each candidate frame. Faster R-CNN consists of two main components which are the Region Proposal Network (RPN) and the

Fast R-CNN. The RPN is responsible for generating candidate target frames, and the Fast R-CNN is responsible for classifying and regressing these candidate frames. As mentioned by Ren et al., 2017 and Li et al. 2021 The RPN and Fast R-CNN share the same feature extraction network, which typically uses a classical convolutional neural network.

RetinaNet is an algorithm that addresses the problem of category imbalance in target detection by incorporating Focal Loss, which adjusts the loss function, enabling the model to focus more on difficult-to-classify samples. RetinaNet uses a feature pyramid network (FPN) to coordinate multiscale features, detecting and classifying targets at each scale. RetinaNet is made up of a Feature Extraction Network, a Classification Subnetwork, and a Regression Subnetwork. The feature extraction network extracts features from the input image, the FPN generates the multi-scale feature pyramid, and the classification subnetwork and regression subnetwork execute target classification and positional regression of the features at each scale, respectively as mentioned by Alhasanat et al. 2021, Liu et al. 2020 and Tian et al. 2020. YOLO has an obvious advantage in terms of real-time performance. Compared to Faster R-CNN and RetinaNet, YOLO can finish the target identification task significantly faster in real-time applications such as highways and parking lot.

YOLO network topology is simpler, making it easier to design and deploy. Furthermore, YOLO is able to detect targets globally by making dense predictions over the entire image without additional candidate frame generation steps, making YOLO excellent in handling dense target detection and large target detection in situations where multiple license plates need to be recognized at the same time. YOLO has an obvious advantage in terms of real-time performance. Compared to Faster R-CNN and RetinaNet, YOLO can finish the target identification task significantly faster in real-time applications such as highways and parking lot. YOLO network topology is simpler, making it easier to design and deploy. Furthermore, YOLO is able to detect targets globally by making dense predictions over the entire image without additional candidate frame generation steps, making YOLO excellent in handling dense target detection and large target detection in situations where multiple license plates need to be recognized at the same time.

Since YOLO's release until 2023, there have actually been eight official versions; nonetheless, there are still issues with version selection. With the goal of delivering real-time performance without compromising the caliber of detection findings, the YOLO family of object detection models has continuously concentrated on striking a balance between speed and accuracy. This trade-off has been a recurrent issue in the evolution of the YOLO architecture,

with each iteration aiming to maximize these opposing aims in a new way.

The main goal of the original YOLO model was to achieve fast object detection. Real-time processing was made possible by the model's use of a single convolutional neural network (CNN) to directly predict object locations and classes from the input image. However, the emphasis on speed resulted in a reduction in accuracy, particularly when dealing with small objects or objects with overlapping bounding boxes. To compare them, we need a metric called Average Precision (AP), sometimes known as Mean Average Precision (mAP), which is a widely used metric for evaluating the performance of object identification algorithms. It calculates the average precision across all categories, resulting in a single value for comparing models as mentioned by Terven et al. in 2023.

As can be seen in the official version, v5 v7 and v1 v2 have greater AP values, indicating a higher level of accuracy. However, YOLOv5 has achieved a very stable version, whereas YOLOv8 is still receiving regular upgrades and enhancements. In terms of computing efficiency and accuracy, YOLOv8 has outperformed YOLOv5 and YOLOv7. However, YOLOv5 has strengths in terms of training speed, inference speed, and memory utilization, particularly in applications that require mobile devices or low resources as mentioned by Wang et al. in 2023. Yolov5 will be utilized as the algorithm for target detection.

PROJECT DEVELOPMENT

Figure 1 shows automatic number plate recognition module diagram. The camera takes real-time pictures of the monitoring area and sends the ingestion request to the automatic license plate recognition module. Next, the system uses the YOLOv5 model to identify the vehicle and license plate in the picture, extracts the image of the license plate area from the detection result, and finally recognize the license plate number. Finally, the system responds to the dashboard.

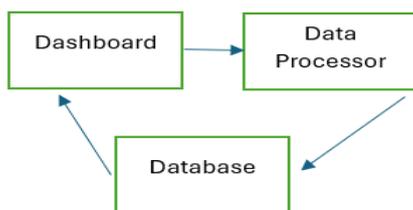


FIGURE 1. Recognition Module Diagram

When the system recognizes a license plate in an image frame acquired by the camera, it begins timing and displays the information on the dashboard. When a user requests to view a record, the database responds and displays it in the GUI as shown in Figure 2. The architecture of system and flow chart as shown in Figure 3 and Figure 4.

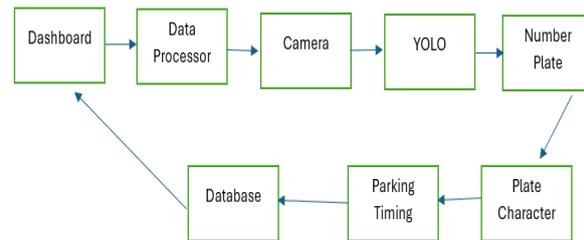


FIGURE 2. Detection Module Diagram

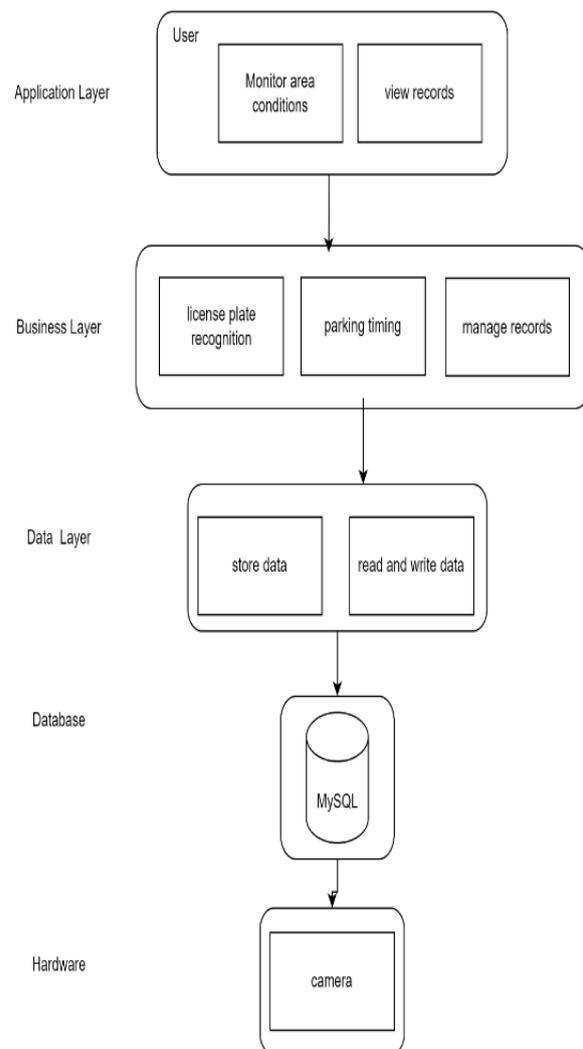


FIGURE 3. Architecture Diagram of the System

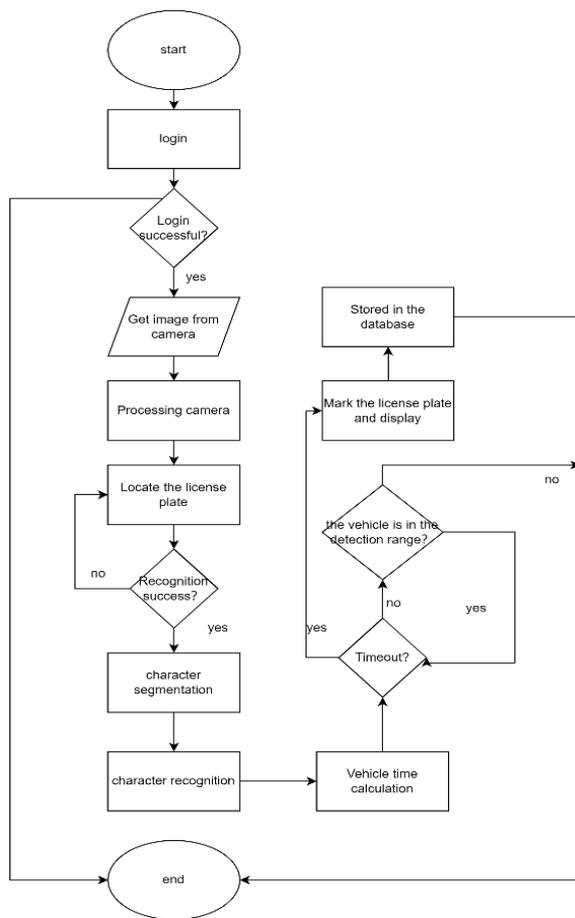


FIGURE 4. Flow Chart

In this project, a login system has been implemented. Since the camera recording includes a specific user's privacy, the user using the system needs to be allowed, which means they need to have the correct password and account number. Furthermore, the recording entity's inclusion makes it easier for users to see past records and do future data analysis. Figure 5 shows a class diagram of the system.

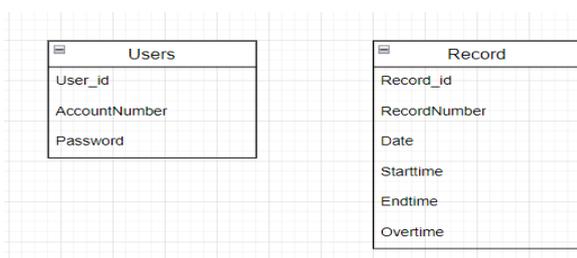


FIGURE 5. Class diagram

Figure 6 shows an interface of main dashboard. The system simply uses a basic graphical user interface (GUI) so that the user may click and interact with the main

functionalities on a single main dashboard, as license plate recognition performance is the system's primary goal.



FIGURE 6. Interface of main dashboard

To design the automated number plate identification system using a bottom-up approach, first create fundamental components: the frame capture service, which interfaces with the camera and captures image frames, and the preprocessing service, which improves image quality. Next, integrate and test the YOLOv5 model for vehicle and license plate recognition, then build the license plate extraction feature and use OCR to turn plate photos into text.

Next, construct the time tracker to track how long a car is parked, and the timeout handler to sound an alert when a vehicle is parked too long. Creating the record storage service and integrating it with a database are steps in the data management and storage process. Create the main dashboard, the record viewing page for historical data, the live monitoring page for real-time monitoring, and the user interface. A login page and an auth service ensure user authentication and access control, guaranteeing proper access controls. In order to make sure the system satisfies all criteria and operates smoothly, perform comprehensive testing, including unit tests, integration tests, and user acceptability testing.

The 20,000 photos in the dataset utilized for this project were downloaded from the internet and feature pictures of cars with license plates from various Chinese provinces, including new energy electric vehicles with green backgrounds. The photos were taken from various angles. They differ in terms of brightness and meteorological conditions. The 20,000 photos up top adhere to the same set of standards. Table 2 shows a dataset specification for the dataset.

TABLE 2. Dataset Specification

Attributes	Specification
File format	PNG
Stored size	20KB~220KB
Image size	720 x 1160
Image bit depth	24 bit
Resolution	96 DPI

RESULTS AND DISCUSSION

The YOLO version 5 model demonstrated high accuracy in detecting vehicles within the monitored area. The Optical Character Recognition (OCR) module successfully extracted and converted license plate images into text with a high degree of accuracy. The system accurately tracked the duration each vehicle remained within the monitored area. Vehicles that exceeded the predefined time limit were correctly identified. The notification system reliably sent alerts to users when a vehicle overstayed, allowing for timely intervention. Users found the dashboard intuitive and easy to navigate. It provided real-time monitoring, historical data access, and alert management effectively. Users could easily view and manage records of detected vehicles, including entry and exit times, which enhanced overall usability. While the system was generally responsive, there were instances of delayed detection due to hardware limitations. This issue affected real-time performance but did not compromise accuracy. The system met its primary goals of accurately detecting vehicles and recognizing license plates.

The integration of YOLOv5 and OCR technologies proved to be effective. The system’s ability to track vehicle dwelling time and send notifications for overstays addressed the problem of unauthorized parking effectively. The modular approach facilitated easy maintenance and potential scalability. Each component, from image capture to notification, functioned seamlessly within the system. Python and YOLOv5 were appropriate choices for this application. However, the hardware used (camera and processing unit) posed limitations on real-time performance. Compared to traditional surveillance systems, this system offers higher accuracy in vehicle and license plate recognition, automated time tracking, and real-time notifications. The primary limitation was the response time delay, which could be mitigated by upgrading the hardware. This is a common issue in systems requiring real-time processing and high computational power. Figure 7 shows a result by set a time and capture a vehicle exceed the time limit. According to Figure 7, out of the 17 cars that were evaluated using the algorithm, 88.23% cars were identified, and their duration was measured. The vehicle has

continuously been viewed by the camera, and the exceeding of the time limitations has been identified. Two car plate numbers were not found.

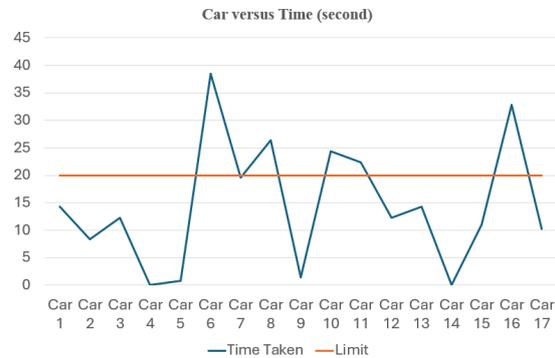


FIGURE 7. Result

CONCLUSION

This project successfully produced a system that recognizes vehicles and license plates, tracks overstay time, and labels overstayed vehicles, achieving all of its goals. Among the three primary functional criteria, the YOLOv5 model was used to achieve excellent detection accuracy under various circumstances. The timeout alert is implemented by comparing the timeout threshold to the time of stay after license plate recognition to update the timeout status. Finally, by writing and reading data in the database, it realizes the need to check the parking record. In terms of performance, the system has a 0.5-second latency and requires improvement. In terms of precision, it may maintain the system’s detection and identification. Camera with AI configuration fail to detect car plate number due several aspect such as in technical or environmental factor. These issues can be explored in order to identify a problem and improve the efficiency of the system. Based on scalability, the system’s variable timeout threshold range allows for some expansion. In terms of security, security feature has been developed using a login mechanism. To summarize, counting time is one possibility that might be considered to improve the road management system.

ACKNOWLEDGEMENT

Deepest gratitude to University Sains Malaysia for their invaluable support and resources that made this work possible. The dedication and expertise of the team at School of Computer Science were instrumental in the success of this project.

DECLARATION OF COMPETING INTEREST

None.

REFERENCES

- Al-Ajarma, K. 2021. After Hajj: Muslim pilgrims refashioning themselves. *Religions* 12(1): 36.
- Al-Hasanat, M., Alsafasfeh, M., Alhasanat, A., & Althunibat, S. 2021. RetinaNet-Based Approach for Object Detection and Distance Estimation in an Image. *International Journal on Communications Antenna and Propagation (IRECAP)* 11(1): 1-9.
- Gazzawe, Foziah & Marwan Albahar. 2024. Reducing traffic congestion in makkah during Hajj through the use of AI technology. *Heliyon* 10(1):1-15.
- Gong, B., Ergu, D., Ying, C., & Ma, B., 2020. A method for wheat head detection based on Yolov4. 1-24.
- Han, J., Liao, Y., Zhang, J., Wang, S., & Li, S. 2018. Target fusion detection of LiDAR and camera based on the improved YOLO algorithm. *Mathematics* 6(10): 1-16.
- Huang, R., Jonathan, P., & Cuixian, C. 2018. YOLO-LITE: a real-time object detection algorithm optimized for non-GPU computers. *2018 IEEE International Conference on Big Data (Big Data)* 2503-2510.
- Jamtsho, Y., Panomkhawn, R., & Rattapoom, W. 2021. Real-time license plate detection for non-helmeted motorcyclist using YOLO. *ICT Express* 7(1): 104-109.
- Jamtsho, Y., Riyamongkol, P., & Waranusast, R. 2020. Real-time Bhutanese license plate localization using YOLO. *ICT Express* 6(2): 121-124.
- Jiang, P., Ergu, D., Liu, F., & Cai, Y., & Ma, B. 2022. A Review of Yolo algorithm developments. *Procedia Computer Science* 199: 1066-1073.
- Laroca, R., Severo, E., Zanlorensri, L. A., Oliveira, L. S., Goncalves, G. R., Schwartz, W. R., & Menotti, D. 2018. A robust real-time automatic license plate recognition based on the YOLO detector. *2018 International Joint Conference on Neural Networks (IJCNN)* 1-10.
- Li, W., 2021. Analysis of object detection performance based on Faster R-CNN. *Journal of Physics: Conference Series* 1827:1-10. IOP Publishing.
- Lin, J. P., & Sun, M. T. 2018. A YOLO-based traffic counting system. *Conference Proceedings - Conference on Technologies and Applications of Artificial Intelligence (TAAI)* 82-85.
- Liu, J., Jia, R., Li, W., Ma, F., Abdullah, H. M., Ma, H., & Mohamed, M. A. 2020. High precision detection algorithm based on improved RetinaNet for defect recognition of transmission lines. *Energy Reports* 6: 2430-2440.
- Lu, J., Ma, C., Li, L., Xing, X., Zhang, Y., Wang, Z., & Xu, J. 2018. A vehicle detection method for aerial image based on YOLO. *Journal of Computer and Communications* 6(11): 98-107.
- Macmillan, Palgrave Palgrave. *The Statesman's Yearbook 2024: The Politics, Cultures and Economies of the World*. Springer Nature, 2022.
- Owaidah, A., Oлару, D., Bennamoun, M., Sohel, F., & Khan, N. 2023. Transport of pilgrims during Hajj: Evidence from a discrete event simulation study. *PLoS One* 18(6):1-32.
- Redmon, J., Divvala, S., Girshick, R., & Farhadi, A. 2016. You Only Look Once: Unified, Real-Time Object Detection. *Conference Proceedings - IEEE Conference on Computer Vision and Pattern Recognition (CVPR)* 779-788.
- Rekha, B. S., Mariam, A., Srinivasan, G. N., Shetty, S. A. 2020. Literature survey on object detection using YOLO. *International Research Journal of Engineering and Technology (IRJET)* 7(6):3082-3088.
- Ren, S., He, K., Girshick, R., Sun, J. 2017. Faster r-cnn: Towards real-time object detection with region proposal networks. *Conference Proceedings – IEEE Transactions on Pattern Analysis and Machine Intelligence* 39:1137-1149.
- Tian, H., Zheng, Y. & Jin, Z. 2020 Improved RetinaNet model for the application of small target detection in the aerial images. *IOP Conference Series: Earth and Environmental Science* 585:1-8.
- Terven, J., Córdova-Esparza, D., & Romero-Gonzalez, J. A. 2023. A comprehensive review of yolo architectures in computer vision: From yolov1 to yolov8 and yolo-nas. *Machine Learning and Knowledge Extraction* 5: 1680-1716.
- Wang, J., Yang, P., Liu, Y., Shang, D., Hui, X., Song, J., & Chen, X. 2023 Research on improved yolov5 for low-light environment object detection. *Electronics* 12(14):3089-3111.
- Zhao, Z. Q., Zheng, P., Xu, S. T., & Wu, X. 2019. Object detection with deep learning: A review. *IEEE Transactions on Neural Networks and Learning Systems* 1:1-21.
- Zou, X., 2019. A review of object detection techniques. *Conference Proceedings - International Conference on Smart Grid and Electrical Automation (ICSGEA)* 2