A novel car license plate and parking slot detection approach based on YOLO

Rishabh
Computer Science and Engineering
KIET Group of Institutions
(rishabh.2024cse1093@kiet.edu)

Pushpendra Kumar
Assistant Professor
Computer Science and Engineering
KIET Group of Institutions
(pushpendra.kumar@kiet.edu)

Vishal Panwar
Computer Science and Engineering
KIET Group of Institutions
(vishal.2024cse1169@kiet.edu)

Vivek Kumar
Computer Science and Engineering
KIET Group of Institutions
(vivek.2024cse1143@kiet.edu)

***Abstract*—The creation of reliable and effective procedures for vehicle monitoring and parking slot management has turned into a crucial research subject as the need for intelligent transportation and parking management systems keeps rising. The implementation of the cutting-edge object detection framework YOLOv8 (You Only Look Once version 8) for the simultaneous recognition of license plates and parking spaces in a controlled environment is thoroughly explored in this research article. The study emphasizes YOLOv8's benefits, such as its real-time detection capabilities and outstanding accuracy, which are essential for practical applications. The study's findings show that the model is capable of reliably identifying car license plates and parking spot occupancy in a variety of lighting situations and vehicle kinds. Along with model performance evaluation, this paper examines practical implementation scenarios, such as integrating the YOLOv8-based solution into existing parking management systems, real-time data analytics, and user experience and traffic management improvements.**

***Index Terms*—YOLOv8, object detection, number plate recognition, car parking slot detection, parking management, real-time detection.**

I. INTRODUCTION

As cities grow and more people buy cars, there is a greater need for good parking and traffic management options. Monitoring parking spots and identifying vehicles by hand takes a lot of time and effort, and mistakes are common. Normal video systems often have trouble giving correct information because of problems like changing lighting, obstacles, and different types of vehicles. In this situation, computer vision and deep learning have become interesting technologies that could help automate and improve these important parts of managing urban infrastructure. Smart parking is one of the basic and most necessary requirements to solve current scenarios. A website says that the average person spends 17 hours a year [1] looking for a place to park their car. This is the reason why the smart parking business is growing and coming up with new ideas. A lot of options put sensors in each parking spot to tell if it's empty or not. But for big parking systems, the cost of the monitor and setting it up is very high. There is also the issue of sensor data that is either useless or lacking in useful information, such as the number plate number. To get more information, you could put a camera in every parking spot, but this would be very expensive and need a strong network. Also, getting all the data from all the cameras would take a lot of bandwidth. Which is a tough job. We came up with a way to balance cost and service quality that system uses image processing to tell if the car is there and gives details like how many parking spots are available. CCTV cameras take pictures, which are then processed by the system to figure out how many parking spaces are open. This system will be built using picture processing methods that will be used in every step of the process. With this system, you can find out how many parking spots are open. When drivers join the parking lot, it will be good for everyone.

II. LITERATURE REVIEW

In this, we have written about the authors, about research paper findings its database, and limitations

- Annalsofrscb. Ro. elite, [2]
  Findings:-
  - Image processing can be used to make an automated parking system that can keep track of how many cars are parked and how many spots are empty. This is one of the most important things that this study found. This would help people save time and find a better way to park instead of having too few spots.
  - The system uses edge detection techniques to capture and process images of parking slots with and without cars, resulting in the identification of the number of free parking slots
  - The paper also discusses the comparison of various applications, including the Car-Park Occupancy data system (COINS), locating vehicles during parking using image processing, and a parking guidance device using RFID and Image Processing Technique in WSN Environment.

- Limitations:-
  - The article neglects to assess the reliability and precision of the image processing technique in detecting parking spaces for automobiles.
  - The research does not adequately consider potential challenges or restrictions that may arise when implementing the proposed method in real-world parking scenarios, such as those involving various types of vehicles, obstructions, and illumination.The paper does not address the potential privacy and security concerns associated with using image processing techniques for car parking slot identification, such as the risk of unauthorized access to the captured images.
  - The effectiveness of the proposed method in comparison to alternative options is difficult to ascertain due to the absence of a comparison with pre-existing automotive parking slot identification systems in the article.
  - The feasibility of the proposed system managing sizable parking sites with a substantial volume of vehicles is not examined in the research.
- Mrs.R.AnjanaDevi,elite, [3]
  findings:-
  - The study presents a robust framework that employs a deep convolutional neural network (CNN) and a support vector machine classifier to identify parking occupancy. The system demonstrated accurate detection rates of 96.7 percent for the researchers' own dataset and 99.7 percent for the publicly available dataset. This demonstrates the remarkable ability of the technique to offer an inexpensive and consistent solution to Car Parking Guidance and Information (CPGI) systems in outdoor environments.
  - Proposed system aims to automatically identify every parking slot in the camera using deep learning. Deep learning, a branch of Artificial Intelligence, allows computers to learn complex perception tasks at a human level of accuracy, including image classification, object detection, and more.
  - The system utilizes image processing techniques such as gray scale conversion, thresholding, canny edge detection, morphological transformation, and contour detection to process the input images and compare them with the dataset to determine the occupancy or vacancy of the parking slot.
  - As with the human brain, deep learning algorithms are capable of addressing complex problems involving diverse and interconnected datasets due to the fact that they acquire knowledge from vast quantities of data. They enable the design of intelligent systems that can learn from complex andlarge-scale datasets.

  Datasets:-
  - The study used public datasets (PKLot) with different intensity and weather conditions for training and testing the deep CNN and SVM classifier.
  - The paper mentions the use of image processing techniques, such as grayscale conversion, thresholding, canny edge detection, morphological transformation, and contour detection, to process the input images for comparison with the dataset.
  - In addition, the study describes the utilisation of a support vector machine (SVM) classifier for the purpose of classification, as well as a pre-trained deep convolutional neural network (CNN) for the retrieval of features from the images.
  - The paper includes captured images and output images generated after image processing using the CNN and SVM classifier.

  Limitations:-
  - The paper does not explicitly mention the limitations of the proposed framework or the image-based detection methods used for parking occupancy detection.
  - The paper does not discuss any potential challenges or drawbacks associated with the implementation of the deep CNN and SVM classifier for parking space detection.
  - The paper does not provide information on the scalability or generalizability of the proposed framework to different parking environments or conditions.
  - The paper does not mention any limitations related to the computational requirements or processing time of the deep learning approach used in the study.
- Hanae Moussaoui,elite, [4]
  Findings:-
  - This research describes a system that identifies and recognises Arabic and Latin number plates by utilising YOLOv7 and image processing techniques.
  - The method achieves an accuracy of 99.3% on four datasets for license plate detection and a recognition precision of 98% for license plate information recognition.
  - Object detection, localization, and recognition are important components of license plate detection and recognition systems.

  Dataset:-
  - The article does not specify on which dataset the algorithms for detecting and identifying Arabic and Latin licence plates were trained.
  - However, the paper mentions the creation of a dataset for image acquisition as one of the steps involved in OCR (Optical Character Recognition) technology.
  - The paper also refers to the use of a labeled dataset for license plate detection and recognition, as shownin Figure 3.
  - For training and testing their licence plate recognition and identification system, the authors likely constructed their own dataset; however, the sources do not specify the nature of that dataset.

  Limitations:-
  - Regarding the inadequacies of the method in utilising image processing techniques and YOLOv7 to detect and identify Arabic and Latin licence plates, none of the available materials addressed the matter.
  - The sources do not provide information about any

potential challenges or drawbacks of the approach.
  - Consider that the limitations of the method may vary depending on the specific implementation and dataset under consideration.
  - Further research or additional sources may be required to obtain a comprehensive understanding of the limitations of the proposed method.

- Hendry,ELITE [5]
  Findings:-
  - The study is mostly about how to use the YOLO structure to find car licence plates. It was able to find licence plates 98.22% of the time and recognise them 78% of the time. A rolling window process reads each number on the number plate, and then a single YOLO structure reads each window. One detection and recognition step is taken by each picture that comes in. This process takes between 800 ms and 1 s. People also test the system in a number of tough situations, such as when the background is rainy, when it's dark, when there isn't much light, and when the pictures have different hues and saturations.
  - Images that are fed in are broken up into N x N grid cells. Each grid cell predicts only one thing. That's how YOLO works. YOLO can only find things that are close, though, because when one of the boxes intersects with another, it stops other boxes from finding the object.
  - We compare the new SWSCD-YOLO method to older ones to see how well it finds licence plates. Clustering, two-way learning, and approaches based on CNN are some old ways of doing things.

  Dataset:-
  - The study makes use of the AOLP collection. There are 2049 pictures of Taiwanese car plates on it. Picture were taken in different places, at different times, and when there was different weather and traffic. There are three sections: Access Control (AC), Road Patrol (RP), and Traffic Law Enforcement (LE). What makes each group unique is where the camera is put, the width of the plate, how it is oriented, and the image conditions. There are 100 pictures in the test set and 581 pictures in the training set. This set of licence plates gives you a variety of situations to test the method for finding and recognising licence plates.

Limitations:-
  - Because of how YOLO works, it can only find objects that are relatively close. If two or more bounding boxes meet, one object stops the other boxes from finding it.YOLO’s one-object rule restricts how close the de- tected object can be, which can limit the accuracy of license plate detection in cases where license plates are closely spaced.
  - YOLO is constructed with twenty-seven convolutional neural network (CNN) layers. Two of these levels are fully interconnected, with the remaining level serving as a detection layer. While this architecture allows for efficient real-time processing, it may not be suitable for detecting small objects in tight spaces.
  - YOLO's sliding-window processing method might not work best in all situations because it needs to find each type of object (plate, digit, and letter) in a picture in a sliding-window way. This can cause more than one item to be found in the same place.
  - YOLO’s performance may be affected by variations in lighting conditions and colors of the car body and license plate, as it primarily relies on edge detection and color differentiation for license plate detection.

- Mr.S. Amarasooriya, Elite [6]
  Findings:-
  - The proposed system possesses the capability to discern the type of vehicle and the number of available parking spaces, thereby streamlining the parking search process and generating time savings.
  - The Yolo algorithm, renowned for its superior accuracy compared to the Canny Edge detection approach, is employed by the system to identify vehicles.
  - The assessment of parking space condition involves calculating the average pixel value for each vehicle. If the average pixel value is contained within the designated bounding box, the slot is considered filled; otherwise, it is considered vacant.
  - With an extensive variety of camera angles and atmospheric conditions, the system maintained an accuracy rate in excess of 95%.
  - The research primarily aims to reduce congestion in the parking sector by enhancing the identification of parking slots..
  - Future researchers may use an online parking management system to concentrate on the allocation of specific spaces and security parking systems.

  Dataset:-
  - The study report makes reference to the PKLot dataset, which consists of 695,899 images of segmented parking spaces and 12,417 images of parking lots. Parking sites in Curitiba, Brazil, were the setting for photographs, and the dataset was manually inspected and numbered. For more than thirty days, the dataset was gathered at five-minute intervals using an inexpensive high-definition camera mounted on a structure.
  - The PKLot dataset was used to find the accuracy of the system in identifying parking slots and vehicles. The collection contains photographs taken in a variety of weather conditions and from a variety of parking lots, each with its own distinct qualities.
  - The accuracy of the system was trained and evaluated utilising this dataset across various weather conditions and with photographs captured from different perspectives. Approximately 95% precision was achieved using the method.
  - The dataset was used to identify the coordinates of each parking slot and assign a unique number to each slot.
  - The dataset was used to refine the detection of parking

slots and potentially minimize congestion in the parking sector.
- The dataset was used to develop a cost-effective automatic parking system that makes it easier for drivers to locate available parking spaces.
- The dataset was used to manage large parking areas by using several cameras.
  - Using the dataset, a guiding information display was implemented to provide vehicles with real-time parking lot information.
  - The dataset was utilised to optimise the performance of the system through adjustments to the camera's orientation in order to capture the entirety of each parking space.
  - Based on the data at hand, scholars concluded that motorists in metropolitan areas spend, on average, ten minutes searching for a parking space..
  - The dataset was used to address the issues of waste of time, congestion, CO2 emissions, and road accidents associated with inefficient parking systems.
  - An automated system was developed utilising the dataset to reduce the effort and time required for parking place searches.
  - The dataset was used to develop a system that improves the effective use of resources and public health by reducing the problems caused by inefficient parking systems.
  - The dataset was used to develop a system that provides useful parking lot information to drivers, reducing their frustration and improving their experience.
  - Using the dataset, a system was implemented to monitor the condition of each parking space. The outcome is exhibited at the car park's entry subsequent to the parking of a vehicle.
  - The dataset was used to develop a system that displays the currently accessible, complimentary parking spaces in close proximity to the drivers' destinations.
  - The dataset was used to develop a system that displays the message of ”parking area is full” if every parking space is occupied.
  - Using the dataset, a system that displays available parking spaces to vehicles for free was developed..

Limitations:-

- The system relies on cameras as sensors, which may have limitations in terms of coverage and accuracy. It requires one or more cameras to cover the desired area, and the accuracy of vehicle detection may vary depending on the camera positioning and image quality.
- The system’s accuracy in detecting parking slots and vehicles is approximately 95%, which means there is still a possibility of false positives or false negatives.
- Conditions such as sunny, damp, and dreary weather can potentially affect the efficiency of the system. Despite the system having undergone testing in diverse weather conditions, extreme weather conditions may continue to present obstacles.
- The capacity for labelling parking spaces is limited by the training model and the area captured by the camera. There may be restrictions on the number of parking spaces that the system can accurately detect and oversee.
- Availability and reliability of the training and testing datasets are further variables that may influence the performance of the system. Although the PKLot dataset is substantial and valuable for the present investigation, concerns may arise regarding its representativeness and the generalizability of its findings to various parking lots.

- S.Sunmathi , Elite, [7]

Findings:-

- The proposed smart car parking system utilizes image processing, IoT, Wi-Fi, and sensors to identify free parking slots, calculate parking charges, and update slot availability in real-time.
- The system aims to address the increasing difficulty in finding parking areas and the resulting traffic congestion.
- Sensors are used to identify free slots, while image processing is employed to identify vehicles.
- The system also includes features such as updating slot availability on a website in real-time and providing a user-friendly interface for accessing parking information.
- The use of infrared sensors helps detect obstacles in the path of infrared light transmission, indicating the presence of a car in a slot.
- Other related systems mentioned in the sources include the use of wireless sensor nodes, geomagnetic sensors, ultrasonic and magnetic sensors, and IoT modules for monitoring parking spaces and providing information to drivers.
- However, the sources do not provide specific findings or results related to the performance or effectiveness of the proposed Clever vehicle parking system.

Dataset:-

- The provided sources do not mention any specific dataset used in the implementation of the smart car parking system.
- There is no information regarding the collection or utilization of a dataset for image processing or any other aspect of the system.
- The focus of the papers is on the use of image processing, IoT, Wi-Fi, and sensors for identifying free parking slots, calculating parking charges, and updating slot availability in real-time.
- The papers primarily discuss the system architecture, working principles, and advantages of the proposed smart car parking systems.
- Therefore, there is no relevant information available in the provided sources regarding the dataset used in the context of the smart car parking system.

Limitations:-

- The paper does not mention any specific limitations or challenges faced during the implementation of the Clever vehicle parking system.
- No information is provided regarding the accuracy or reliability of the image processing algorithm used for vehicle identification.
- The paper does not discuss the potential issues or drawbacks of using IoT and Wi-Fi for updating the availability of free slots on a website in real-time.
- The suggested system's scalability is not mentioned. That is, it is not said if it can handle a lot of parking spots and cars at the same time.

III. RESEARCH METHODOLOGY

Here we are using two models of Yolo. These sections describe the model research methodology:-
A describes the Number Plate Detection Methodology.
B describes the Car Parking Slot Detection Methodology.

A. Research Methodology of Number Plate Detection

Here we are going to first extract the image of car from live-stream. After that we are going to extract the license plate number from the car. Now by using YOLOV8 we will extract the characters from the license plate after that our model will extract the license number of car.

- **Data Collection:- :-** The first thing that needs to be done is to take pictures from various vehicles. The images were captured at various times of the day and from various perspectives to ensure that the system could adapt to changes in the locations and motions of the objects. To check if the YOLOV8 type could locate the number plate number, tests were conducted on it. The dataset demonstrates how to locate a moving car's number plate number using the YOLOV8 approach. We also teach our method via live video streams in order to do this.
- **WorkFlow of yolov8 model is:-**

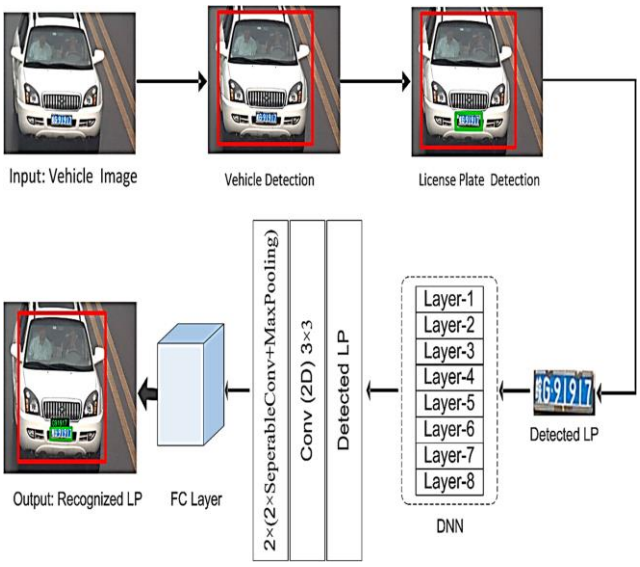


Fig. 1. workflow of number plate detection

- **Data Flow of our model is:-**

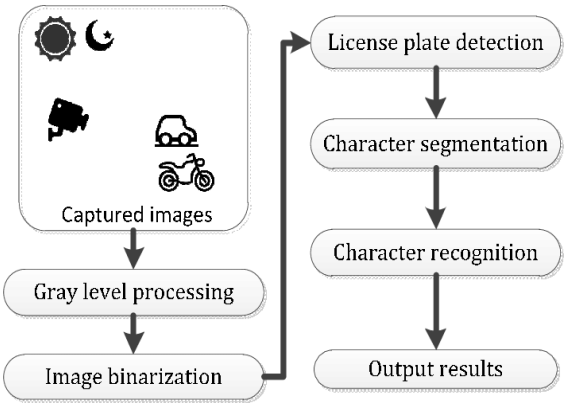


Fig. 2. data flow of number plate detection

B. Research Methodology of Car Parking Slot Detection

It's important to remember that the lines between the parking spots must be clear, unblocked, and easy to see while setting up. When the app first starts up, it will look at the shape of the picture to figure out how big, tall, and long it is. The open parking spot is then found by looking at the pictures that were found. First, a picture of the parking spot will be taken. This picture will then be used for more work.Next, the system will extract the image from the Database Management system (DBMS) for comparing the obtained image with the dataset in the database which consists of the image of a vehicle in parking space and a vacant parking slot without any vehicle. Now the images will not be compared directly after fetching as it requires some image-processing techniques to compare the two images at the most precision. So the next step will be processing the image for accurate comparison to find out the unparked slots in the parking space. For this, input image will be processed in the segmentation process which contains the following steps In this model, we use the YOLO model to detect the slot and mark that slot by some color ie, yellow, and name that slot to slot1. Now this model detects the vehicle and marks it in box whose boundary is red name it as slot2. after that if both the boxes say slo1 and slot2 are overlapping then it say to be occupied otherwise, unoccupied.

- **Data Collections:- :-** First, shots need to be taken from a building with more than one level. To make sure the system could handle changes in light and weather, it was shot in a variety of weather conditions and at various times of day. That's how we tested the YOLO model for cars. The data set tells the YOLO method how to find

- **WorkFlow of our model is:-**

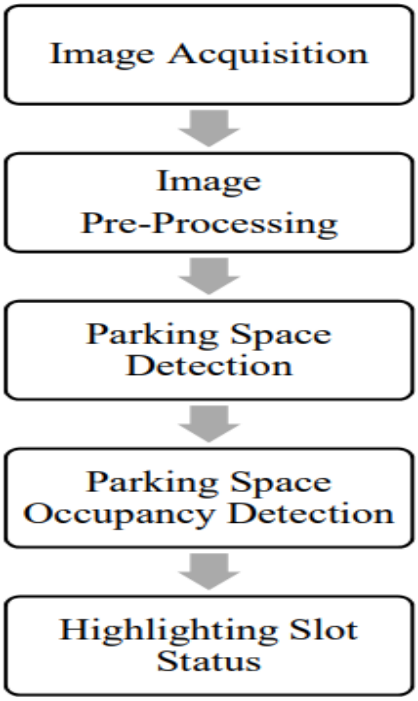


Fig. 3. workflow of parking slot detection

- **Data flow of our parking slot is:-**

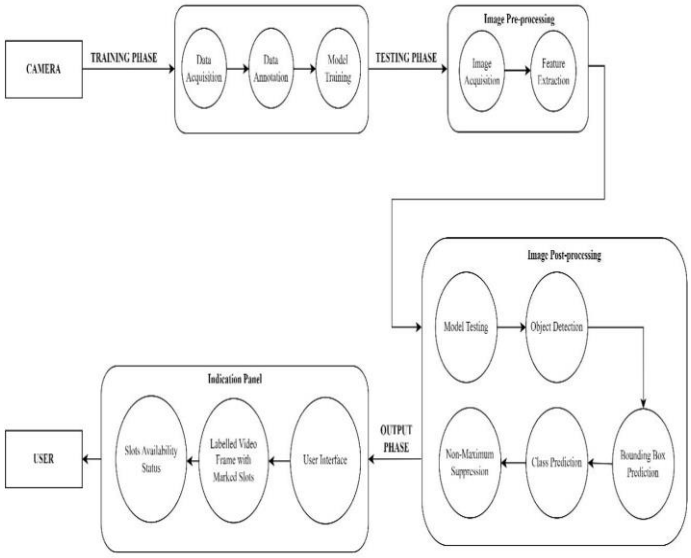
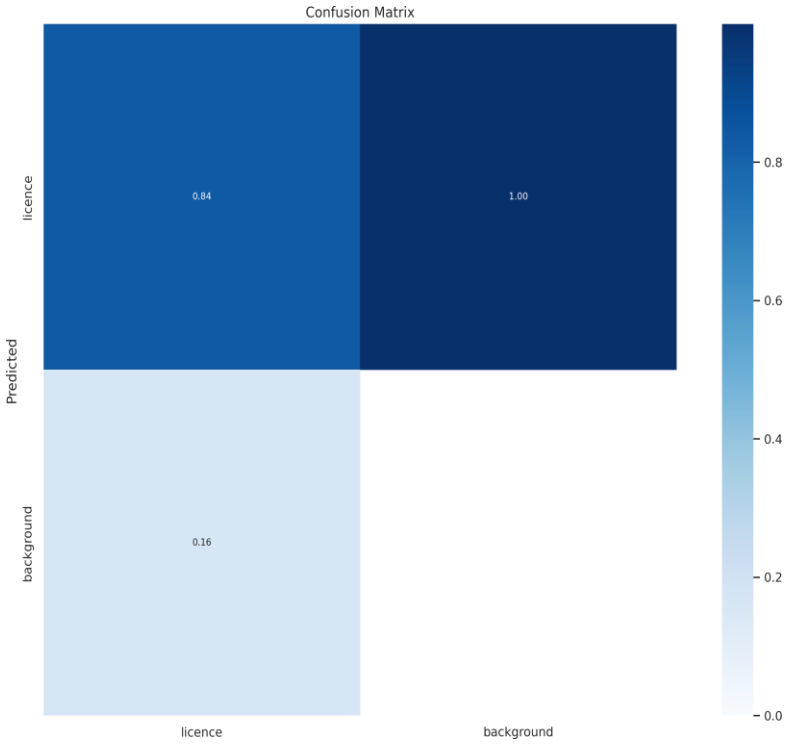


Fig. 4. Data flow parking slot detection

Screen Shots of our results are:-



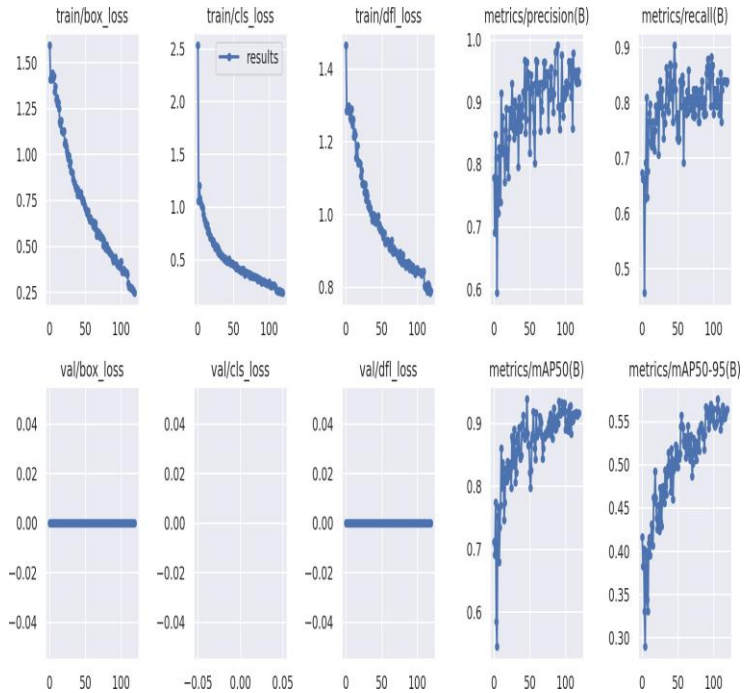


Fig. 5. Confusion Metrics

IV. RESULTS

I. Results of License plate Detection

The tests proved that the YOLOV8 algorithm can correctly detect the car license plate number. This means that the YOLOV8 algorithm can correctly identify 84% of the car license plate number in a video. The YOLOV8 algorithm is good at detecting the car license plate number, as shown by the confusion matrix and by the Training and the Validation Loss.

Fig. 6.Data and Training Loos

II. Results of Parking slot Detection

The tests proved that the YOLO algorithm can correctly identify the parking spots and cars in pictures taken from the parking lot. This means that the YOLO algorithm can correctly identify 92% of the parking spots and cars in the images. The Average Precision (AP) for the algorithm is 0.92. Also, both the precision and recall scores were very high, at 0.926 for precision and 0.92 for recall. The YOLO algorithm is good at finding parking spots and cars in real-world pictures, as shown by these results.

- **Evloution Matrix is:-**

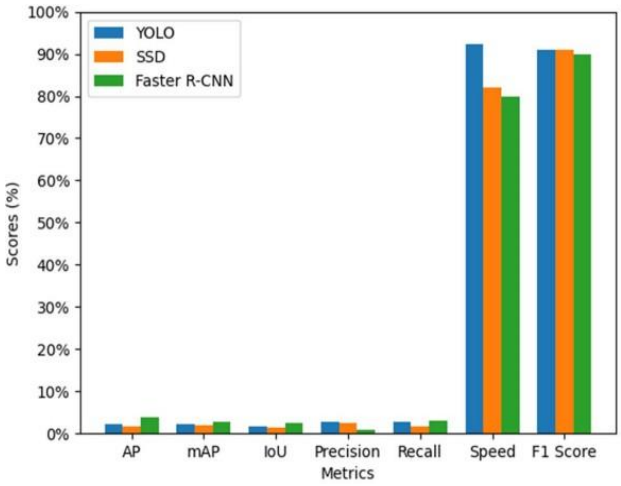
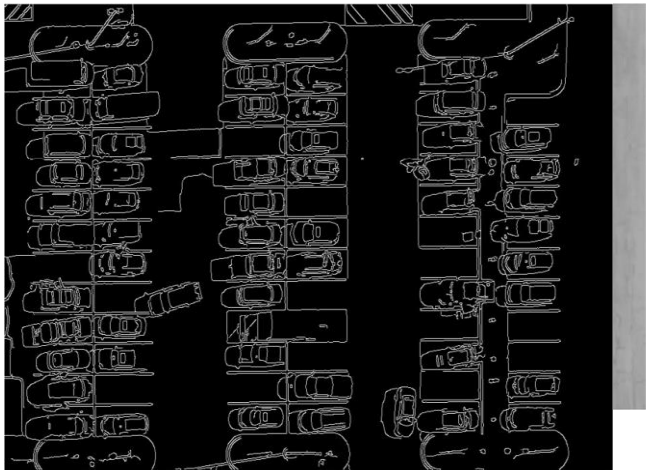
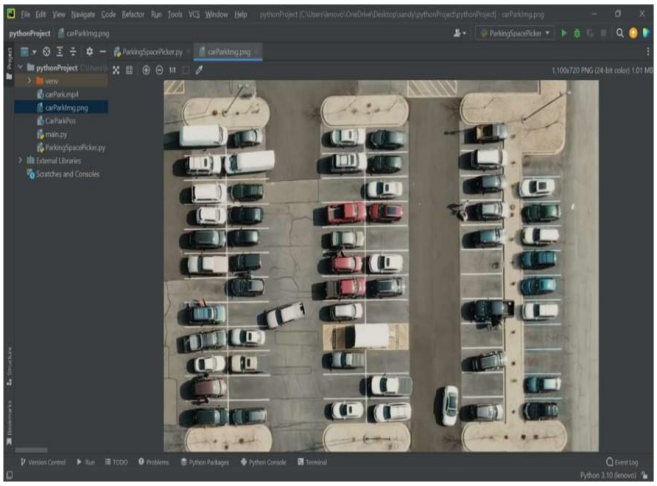


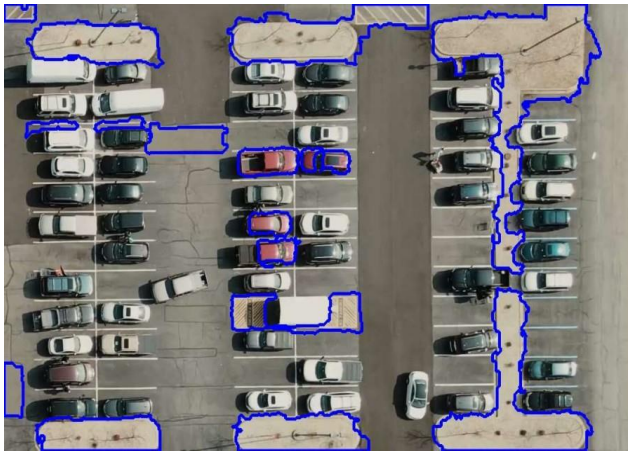
Fig. 7. Evaluation Metrics

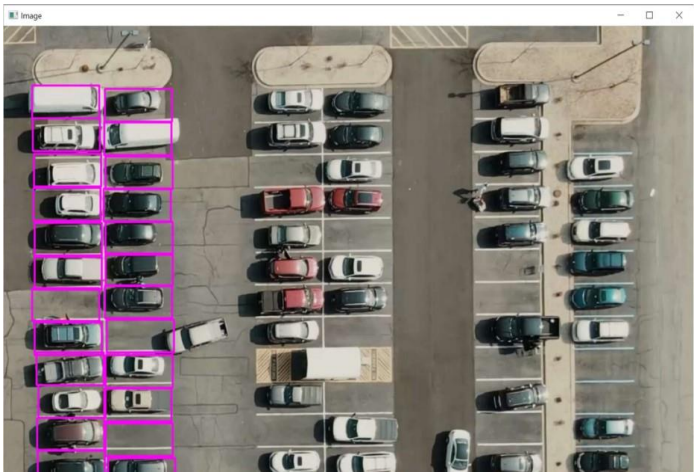
The tests were compared to other object recognition algorithms, such as the faster R-CNN and Single-Shot Detector (SSD) algorithms. YOLO did better in terms of speed and accuracy than these other algorithms. The YOLO algorithm is faster than the others because it only needs one forward pass of the network to find multiple items. Other algorithms need more than one pass.

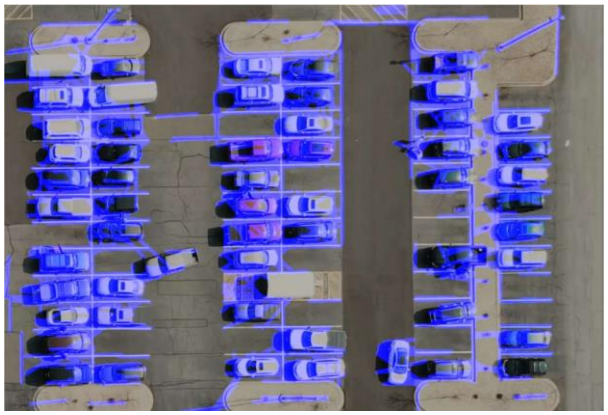
ScreenShots of our results are:-

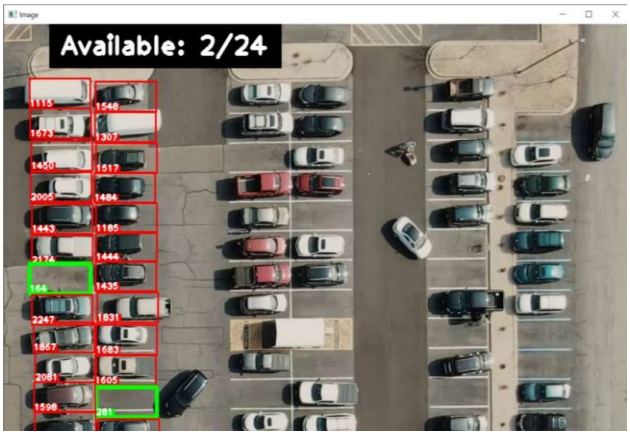












V. CONCLUSION

– The YOLOV8 algorithm is used to create a method for number plate detection in this study. Video of cars are used to test and teach the system. Through tests, it was shown that the YOLOV8 algorithm can correctly detect license plate numbers and cars in video using an AP. People looked at the results and compared them to other object recognition algorithms. YOLOV8 did better in terms of speed and accuracy than the other algorithms. We can learn a lot from the results of this study about how to make parking systems

smarter. The use of YOLOV8 in this study showed that it is possible to make a fast, accurate, and reliable method for detecting the car license plate number that can be used in the real world. These findings may make parking cars faster and easier. In conclusion, the method for detecting the car license plate number that was built in this study looks like a good way to detect the car license plate number and cars in real- world pictures. People who use YOLOV8 have shown that it is possible to make a method that works well and is accurate that can be used in the real world. More work could be done in the future to make the system work better by using more advanced deep-learning methods and adding more data.

The YOLO algorithm is used to create a method for finding parking spots for cars in this study. Picture sets from a multi-level parking garage are used to teach and verify the system. Through tests, it was shown that the YOLO algorithm can correctly find parking spots and cars in pictures using an AP. People looked at the results and compared them to other object recognition algorithms. YOLO did better in terms of speed and accuracy than the other algorithms. We can learn a lot from the results of this study about how to make parking systems smarter. The use of YOLO in this study showed that it is possible to make a fast, accurate, and reliable method for finding parking spots that can be used in the real world. These findings may make parking cars faster and easier. In conclusion, the method for finding parking spots for cars that was built in this study looks like a good way to find parking spots and cars in real-world pictures. People who use YOLO have shown that it is possible to make a method that works well and is accurate that can be used in the real world. More work could be done in the future to make the system work better by using more advanced deep-learning methods and adding more data.

(a) FUTURE SCOPE

- **Improvement in parking efficiency:-**

– These models of our car parking slot and number plate detections can be used in creating applications or APIs for car parking on a campus which helps users find the parking slot easily and prevents users from wasting time in finding parking areas.

– Use real-time information about which parking spots are occupied and which ones are open to efficiently handle parking spaces.

– Give people a website or app that they can use to see what parking spots are available and book them ahead of time.

– **Data Analytics and Insights:-** Use the system's data to learn more about parking patterns, peak times, and general traffic patterns. This will help you plan cities and allocate resources more efficiently

– **Enhanced Security and Safety:-** Implement features such as stolen vehicle detection by alerting authorities when a recognized number plate matches a database of stolen vehicles.

REFERENCES

[1] McCoy, K. (2017, July 12). Drivers spend an average of 17 hours a year searching for parking spots. USA Today. https://www.usatoday.com/story/money/2017/07/12/parking-pain-causes-financial-and-personal-strain/467637001/

[2] View of an efficient car parking slot identification system using image processing. (n.d.). Annalsofrscb.Ro. Retrieved October 22, 2023, from https://www.annalsofrscb.ro/index.php/journal/article/view/4988/3982/

[3] Anjana Devi, M. R., Seethalakshmi,V., Sreenidhi, S. S., Sridevi, S., & Srilekha, B. (n.d.). International research journal of engineering and technology (IRJET). Irjet.net. Retrieved October 22, 2023, from https://www.irjet.net/archives/V8/i4/Specialissue/IRJET − V 8SI38.pdf

[4] Moussaoui, Hanae, Nabil EL AKKAD, and Mohamed BENSLIMANE. "Arabic and Latin license plate detection and recognition based on YOLOv7 and image processing methods." (2023).

[5]Chen, Rung-Ching. "Automatic License Plate Recognition via sliding-window darknet-YOLO deep learning." Image and Vision Computing 87 (2019): 47- 56.

[6] Amarasooriya, P. M. D. S. & Peiris, M. P.P.L (2022). Implementation of Smart Parking System Using Image Processing. 13th International Conference on Business & Information ICBI, University of Kelaniya, Sri Lanka. ISSN 2465-6399 (pp. 456-465)

[7] Sunmathi, S., M. Sandhya, M. Sumitha, and A. Kirthika. "Smart car parking using image processing." In 2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS), pp. 485-487. IEEE, 2019.

[8] Idris, M. Y., E. M. Tamil, Z. Razzak, and N. M. Noor. "Smart parking system using image processing techniques." Journal of Information Technology (2009): 114-127.

[9] Zhongxiang Zhou, Yifei Yang, Yue Wang, Rong Xiong. (2023). Open-Set Object Detection Using Classification-Free Object Proposal and InstanceLevel Contrastive Learning. IEEE Robotics and Automation Letters. 8, pp. 1691 - 1698. IEEE. doi:https://doi.org/10.1109/LRA.2023.3242169

[10] Zhi Xu, Jingzhao Li, Mei Zhang. (2021). A Surveillance Video Real-Time Analysis System Based on Edge-Cloud and FL-YOLO Cooperation in Coal Mine. IEEE Access. 9, pp. 68482 - 68497. IEEE.doi:https://doi.org/10.1109/ACCESS.2021.3077499

[11] Yunfeng Shao, Pengzhen Chen, Tongtong Cao. (2018). A Grid Projection Method Based on Ultrasonic Sensor for Parking Space Detection. IGARSS 2018 - 2018 IEEE International 49 Geoscience and Remote Sensing Symposium. Valencia, Spain: IEEE. doi:10.1109/IGARSS.2018.8519022

[12] Twinkle Singh, Safdar Sardar Khan, Surendra Chadok. (2018). A Review on Automatic Parking Space Occupancy Detection. 2018 International Conference on Advanced Computation and Telecommunication (ICACAT). Bhopal, India: IEEE. doi:10.1109/ICACAT.2018.8933644

[13] Rachapol Lookmuang, Krit Nambut, Sasiporn Usanavasin. (2018). Smart parking using IoT technology. 2018 5th International Conference on Business and Industrial Research (ICBIR). Bangkok, Thailand: IEEE. doi:10.1109/ICBIR.2018.8391155

[14] Matthias R. Schmid, S. Ates, J. Dickmann, F. von Hundelshausen, H.- J. Wuensche. (2011). Parking space detection with hierarchical dynamic occupancy grids. 2011 IEEE Intelligent Vehicles Symposium (IV). Baden-Baden, Germany: IEEE. doi:10.1109/IVS.2011.5940476 [15] Annirudh D, Arun Kumar D, Adabala Taraka Sai Raghava Kumar, K.R.M. Vijaya Chandrakala. (2021). IoT based Intelligent Parking Management System. 2021 IEEE Second International Conference on Control, Measurement and Instrumentation (CMI). Kolkata, India: IEEE. doi:10.1109/CMI50323.2021.9362845

[16] Chin-Kit Ng, Soon-Nyean Cheong, Erfan Hajimohammadhosseinmemar, Wen-Jiun Yap. (2017). Mobile outdoor parking space detection application. 2017 IEEE 8th Control and System Graduate Research Colloquium (ICS-GRC). Shah Alam, Malaysia: IEEE.

doi:10.1109/ICSGRC.2017.8070573

[17] Daniel Padilla Carrasco, Hatem A. Rashwan, Miguel Angel Garc ´ ´ıa, Domenec ` Puig. (2021). T-YOLO: Tiny Vehicle Detection Based on YOLO and MultiScale Convolutional Neural Networks. IEEE Access. 11, pp. 22430 - 22440. IEEE. doi:https://doi.org/10.1109/ACCESS.2021.3137638

[18] Jae Kyu Suhr, Ho Gi Jung. (2016). Automatic Parking Space Detection and Tracking for Underground and Indoor Environments. IEEE Transactions on Industrial Electronics. 63, pp. 5687 - 5698. IEEE. doi:10.1109/TIE.2016.2558480

[19] Mohamed ElMikaty, Tania Stathaki. (2017). Detection of Cars in High-Resolution Aerial Images of Complex Urban Environments. IEEE Transactions on Geoscience and Remote Sensing. 55, pp. 5913 - 5924. IEEE. doi:https://doi.org/10.1109/TGRS.2017.2716984

[20] Ap, N. Palanivel, T. Vigneshwaran, M. Sriv Arappradhan, and R. Madhanraj. "Automatic number plate detection in vehicles using faster R-CNN." In 2020 International conference on system, computation, automation and networking (ICSCAN), pp. 1-6. IEEE, 2020.

[21] Gnanaprakash, V., N. Kanthimathi, and N. Saranya. "Automatic number plate recognition using deep learning." In IOP Conference series: materials science and engineering, vol. 1084, no. 1, p. 012027. IOP Publishing, 2021.

[22] Gupta, Jatin, Vandana Saini, and Kamaldeep Garg. "Multilanguage number plate detection using convolutional neural networks." arXiv preprint arXiv:2008.08023 (2020).

[23] Babu, R. Naren, V. Sowmya, and K. P. Soman. "Indian car number plate recognition using deep learning." In 2019 2nd international conference on intelligent computing, instrumentation and control technologies (ICICICT), vol. 1, pp. 1269-1272. IEEE, 2019.

[24] Hongliang, Bai, and Liu Changping. "A hybrid license plate extraction method based on edge statistics and morphology." In *Proceedings of the 17th International Conference on Pattern Recognition, 2004. ICPR 2004.*, vol. 2, pp. 831-834. IEEE, 2004.

[25] Khan, Khurram, Abid Imran, Hafiz Zia Ur Rehman, Adnan Fazil, Muhammad Zakwan, and Zahid Mahmood. "Performance enhancement method for multiple license plate recognition in challenging environments." *EURASIP Journal on Image and Video Processing* 2021, no. 1 (2021): 1-23.

[26] Al-Shemarry, Meeras Salman, Yan Li, and Shahab Abdulla. "An efficient texture descriptor for the detection of license plates from vehicle images in difficult conditions." *IEEE transactions on intelligent transportation systems* 21, no. 2 (2019): 553-564.

[27] Al-Ghaili, Abbas M., Syamsiah Mashohor, Abdul Rahman Ramli, and Alyani Ismail. "Vertical-edge-based car-license-plate detection method." *IEEE transactions on vehicular technology* 62, no. 1 (2012): 26-38.

[28] Xie, Lele, Tasweer Ahmad, Lianwen Jin, Yuliang Liu, and Sheng Zhang. "A new CNN-based method for multi-directional car license plate detection." *IEEE Transactions on Intelligent Transportation Systems* 19, no. 2 (2018): 507-517.

[29] Selmi, Zied, Mohamed Ben Halima, and Adel M. Alimi. "Deep learning system for automatic license plate detection and recognition." In *2017 14th IAPR international conference on document analysis and recognition (ICDAR)*, vol. 1, pp. 1132-1138. IEEE, 2017.

[30] Chen, Rung-Ching. "Automatic License Plate Recognition via sliding-window darknet-YOLO deep learning." *Image and Vision Computing* 87 (2019): 47-56.

[31] Sultan, Fahd, Khurram Khan, Yasir Ali Shah, Mohsin Shahzad, Uzair Khan, and Zahid Mahmood. "Towards Automatic License Plate Recognition in Challenging Conditions." *Applied Sciences* 13, no. 6 (2023): 3956.