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Design and Implementation of Advance Real Time Parking System

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***Abstract:** Effective parking facility management is critical to the functioning of urban infrastructure, but current systems frequently struggle to reliably identify occupants and neutralize possible threats. In this paper, we suggest a brand-new parking management strategy. The title is "Advanced Real-Time Parking System" . A strong parking management system with machine learning-based threat detection is presented in this paper. Three specialized models were created using YOLO v8 and trained on carefully selected datasets of 800, 800, and 600 images that included license plates, parking occupancy, fires, and explosions. By taking advantage of YOLO v8's flexibility, these models were designed with high detection accuracy in mind. The models underwent thorough training and validation before being smoothly incorporated into a single system that provided extensive surveillance capabilities. The evaluation showed a remarkable accuracy of 92%, demonstrating the effectiveness of the system in actual threat detection situations. This study highlights the potential of YOLO v8-based solutions to improve parking environments' safety and security, demonstrating their adaptability in tackling a range of security issues.*

***Keywords:** Parking Management System, Machine Learning, YOLO V8, Fire and Smoke Detection.*

1. INTRODUCTION

In the last few years, the number of automobiles has increased exponentially. In 2015, there were 210023289 registered vehicles in India, according to a statistic released by the government (Community Data. Gov.in, 2019). The number of automobiles has increased by 17.55 percent on average [1]. Therefore, parking is seen as a major issue in the majority of cities worldwide including other reasons like, growing populations, a shortage of parking spots, traffic congestion on the roads, the placements of parking lots, etc. Finding and providing parking spaces has become difficult for parkers and transportation authorities/owners, respectively, due to the sharp rise in the number of automobiles [2].

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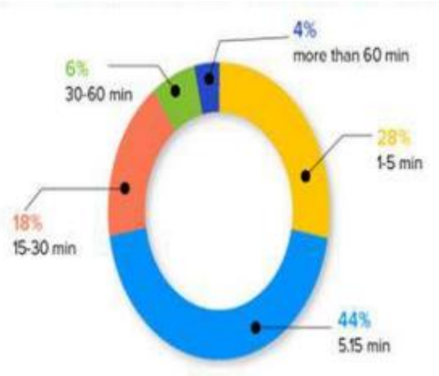

Figure 1. Time spent by drivers looking for parking Spot in a day.

Source: [3]
Furthermore, safety precautions in parking lots are compromised because it is very difficult to look after such large number of vehicles. There is a compromise in accident prevention, which puts pedestrians and cars at greater risk. Furthermore, parking facilities frequently lack adequate fire alarm systems as well as alert systems for any kind of explosion. There is always a potential for fires or explosions caused due electrical problems, vehicle malfunctions, or other unanticipated events, in parking spaces which presents a serious risk to public safety. To reduce these risks and guarantee the security of cars as well as people using parking lots, it is essential to put strong safety procedures in place, such as sophisticated detection mechanism and alarm systems. This Paper focuses on parking lots that are available in public areas, retail centres, and commercial roadways that have designated parking slots. It will be far more efficient to automate the process of identifying parking spaces and all the threats by using video surveillance technology than by using sensor-based labour[3]. Because in a large parking space it is very difficult to deploy large number of sensors and collect their data individually, On the other hand camera cover a relatively large area in their viewing angle making it a handy and cost-effective alternative.
In order to improve the efficiency and safety of parking systems, this research study suggests integrating the OpenCV (Open-Source Computer Vision Library) with the YOLO (You Only Look Once) object detection framework. The suggested model seeks to precisely identify cars and open parking spaces inside parking facilities by utilizing YOLO's real-time object detection capabilities. The single-shot detection method used by YOLO makes it possible to quickly and accurately detect several objects at once, making parking lot monitoring more effective. Furthermore, the incorporation of OpenCV offers a strong foundation for image processing and analysis, which makes the YOLO-based parking slot and vehicle detection system easier to implement. The system can quickly detect possible safety risks and initiate the necessary alerts or interventions by using OpenCV and YOLO for fire and explosion detection. Through proactive identification and resolution of potential hazards in parking environments, this all-encompassing approach not only maximizes the use of available parking spaces but also improves safety protocols. The purpose of this research is to show how the suggested YOLO and OpenCV-based model can improve the efficiency and safety of parking systems through experimental validation and performance evaluation.

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2. LITERATURE REVIEW

An advanced parking system using RFID, sensors, cameras, and a Raspberry Pi 3 for vehicle detection and guidance was proposed by Ravi Kumar Gupta and Geeta Rani [1]. Employees, parents, students, and visitors are all given RFID tags, which make vehicle identification more effective. PIR sensors guarantee correct parking, cameras help with traffic management, and magnetometers detect movement in vehicles. Erroneous parking is indicated by voice messages and LEDs. The system improves parking management by enabling easy vehicle entry and exit. A computer vision and machine learning-based smart parking system is proposed by T. Naga Swathia and V. Megala [2]. Their method uses a mobile app to notify users in real-time of available parking spaces and incorporates technologies such as CNN, OpenCV, React, and machine learning. The system uses automated monitoring and digital payments to improve parking efficiency and lessen traffic.

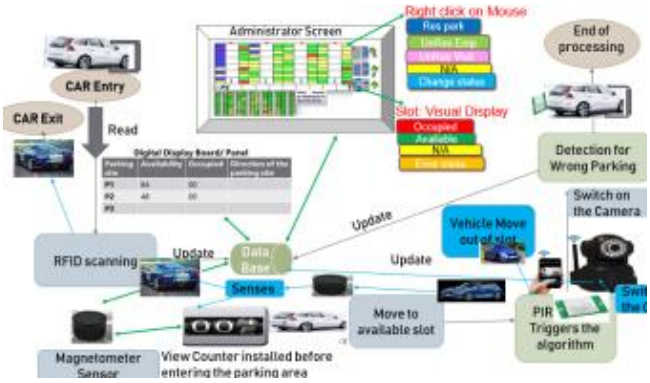

Fig. 2- Mechanism of Parking and Un-parking of a Vehicle.
Source: [1]

Sandeep Saharan and Neeraj Kumar [3] offer a strategy for Seattle's on-street parking management. They pre-process the data, use machine learning models (Linear, Decision Tree, Neural Network, Random Forest) to predict parking occupancy, and then suggest an occupancy-driven pricing plan. The primary normalization equation is:

$$dv_{new}(i) = \frac{dv_{old}(i) - \min(dv_{old})}{\max(dv_{old}) - \min(d_{old})} \quad (1)$$

This approach aims to optimize parking availability, reduce congestion, and enhance revenue generation.
In order to locate license plates, the M. M. Rashid, A. Musa[4] approach for license plate recognition uses a combination of morphological operations and thresholding. It uses methods for optical character recognition (OCR), character segmentation, angular skew correction, and filtering out non-plate objects. The suggested algorithm makes electronic billing easier, directs parking, and extracts license plate numbers. Because of its high accuracy, performance analysis recommends the Mean Square Error (MSE) approach for character recognition.

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Using Internet of Things technology, Mohammad Fokhrul Islam Buian and Iqtiar Md Siddique [5] suggest an online parking management system based on QR codes that allows for effective parking slot monitoring. It uses QR codes to provide easy access to designated areas, real-time parking spot detection, and user authentication. To transmit and visualize data, the system combines ESP8266 Wi-Fi modules, IR sensors, and the ThingSpeak platform. Users can quickly access parking spaces by scanning QR codes, which increases productivity, eases traffic, and enhances the overall parking experience. The initiative places a strong emphasis on automation, user-friendliness, and stakeholder collaboration for efficient parking management and improved urban mobility. Integration with smart infrastructure, scalability, security improvements, user feedback systems, and sustainability integration are all part of the work to come.

A virtual environment containing environment setup, path planning, path tracking, vehicle detection, vehicle counting, and smart parking techniques is presented by Nibedita and Sudhir [6] as an improved smart parking model. The model follows acceleration and driving angle parameters to navigate through the environment using a state vector and input vector. The implementation entails setting up a 24-space parking area, employing computerised guidance to direct cars to open spots, and preserving parking records.

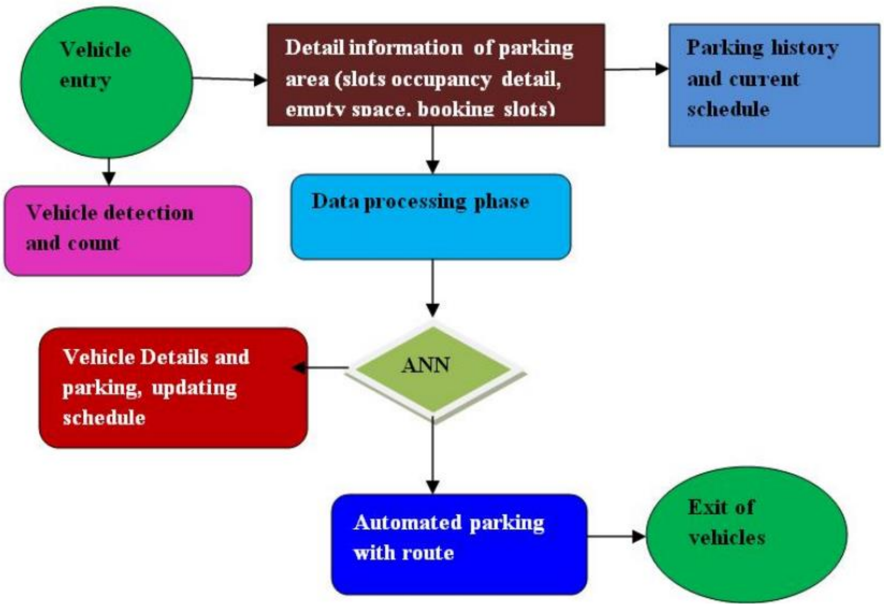

Fig.3-Flowchart of System.
Source: [6]

The suggested parking system by Gongjun Yan and Weiming Yang[7] makes use of hardware and software architectures to guarantee intelligent parking services, security, and privacy. Every car has a short-range wireless transceiver and processor that connects to a network of control computers, parking belts, and other transceivers. Communication and function modules allow for the smooth management of the reservation and check-in procedures. Encryption protects privacy during transactions. The system makes use of check-in, reservation,

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cancellation, and advertising publishing schemes. Furthermore, based on parking dynamics, an intelligent parking management model optimises service classes and forecasts revenue. In order to minimise disruption to parking services and optimise the timing for routine checks, maintenance considerations are also taken into account.

3. METHODOLOGY AND MODEL SPECIFICATIONS

We have used YOLO (You Only Look Once) architecture to detect the different objects in our system like parking slot occupancy, fire and smoke detection and number plate detection.
In computer vision, YOLO (You Only Look Once) is a model architecture and algorithm combination used for object detection. By formulating object detection as a single regression problem and directly predicting bounding boxes and class probabilities from entire images in a single evaluation, the original YOLO algorithm introduced a novel approach. This method differs from earlier techniques that used classifiers on different image regions of interest. Typically, the convolutional neural network (CNN) backbone of the YOLO architecture is followed by detection layers. The detection layers forecast bounding boxes and class probabilities for objects in the image, while the CNN backbone extracts features from the input image. YOLO can accomplish real-time performance in object detection tasks thanks to this architecture.
In this Project we will be using the latest version of YOLO v8. The newest model in the YOLO series of real-time object detectors, YOLOv8, offers cutting-edge accuracy and speed capabilities. For better feature extraction and object detection performance, it has sophisticated backbone and neck architectures. Compared to anchor-based approaches, the model's anchor-free split Ultralytics head leads to improved accuracy and a more effective detection process. YOLOv8, with its emphasis on preserving the best possible balance between speed and accuracy, is appropriate for real-time object detection tasks across a variety of application domains. A wide variety of models, each tailored for particular computer vision tasks, such as object detection, instance segmentation, pose/keypoints detection, oriented object detection, and classification1, are supported by the YOLOv8 series.

Hardware Components used for deploying the System:
Raspberry Pi:
1. Processor: Broadcom B
2. CM2711, Quad-core Cortex-A72 (ARM v8) 64-bit SoC running at 1.5 GHz.
3. Memory (RAM): 8 GB LPDDR4 SDRAM.
4. Storage: MicroSD card slot for storage expansion.
5. Connectivity: Gigabit Ethernet (RJ45), Dual-band 802.11 b/g/n/ac wireless LAN, Bluetooth 5.0/BLE.
6. Ports: 2 × USB 3.0, 2 × USB 2.0, 2 × micro-HDMI, 1 × 3.5mm audio/video jack.
7. GPIO Pins: 40-pin GPIO header.
8. Video & Graphics: Dual display support up to 4K, H.265 (4Kp60 decode), H.264 (1080p60 decode, 1080p30 encode), OpenGL ES 3.0.
9. Operating System Support: Raspberry Pi OS, Ubuntu, other Linux distributions.
10. Power: USB-C power supply port, 5V DC input (3A recommended).

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11. Dimensions: 85mm × 56mm × 17mm.

Figure 4: Raspberry Pi 4-B
Source: amazon [16]

Camera Module for Raspberry Pi:
1. Sensor: Sony IMX219 8-megapixel sensor.
2. Resolution: Up to 3280 × 2464 pixels still capture.
3. Video Resolution: 1080p30, 720p60, and VGA90 video modes 30 FPS.
4. Field of View (FOV): 62.2 degrees diagonal.
5. Dimensions: 25mm × 23mm × 9mm.

Figure 5: Camera Module of Raspberry Pi.
Source: amazon [17]

Parking Space Detection
We started by taking pictures of the empty parking spots in the lot in order to identify them a dataset of about 800 is used. To maintain consistency throughout the dataset, we uniformly

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sized these images. We carefully identified the parking spots in each image, encircling them with boxes and designating whether they were occupied or vacant.

Figure 6: Labelling the free Spaces
Source: Google Colab Repository

The model's ability to identify empty spaces was trained through the labelling process. We prepared the data for training after it was labelled. To ensure that every pixel in the images was in a format that the model could comprehend, this required resizing the images.

$$I' = resize(I, width, height) \quad (2)$$

Where I is the original image and I' is the resized image. The dataset was then split into two sections: one for model training and the other for validation or accuracy testing.

We decided to base our solution on a pre-trained YOLO model. This model was a good place to start because it had previously been trained to recognise a variety of objects on a sizable dataset. Using our labelled dataset, we adjusted the model's parameters to improve its ability to identify empty parking spaces in particular.

To make sure the model was learning efficiently, we continuously adjusted it during the training phase and evaluated its performance on the validation set.

After we were happy with the trained model's accuracy, we put it to use in the parking lot. There, it was able to monitor and identify empty parking spaces by analysing real-time video feeds, which helped with effective parking management. This is how the model was identifying free spaces and cars after it was trained.

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Figure 7: parking slot detection test.
Source: Parking Boxx [14]

Here Pink boxes represent the empty spaces and red one represents the engaged one.

Fire and Explosion Detection

We first assembled a dataset of pictures and videos showing fires and explosions in order to build a system for fire and explosion detection. These were obtained from a number of sources, such as internet databases and security video. For this Particular model we used a dataset of 800 images. We then painstakingly annotated these occurrences, delineating the areas in which explosions and fires transpired, giving the model labelled training data.

We pre-processed the photos and videos in our dataset after it was ready to make sure that their sizes and formats were consistent. This phase was essential for preserving uniformity throughout the dataset and streamlining the model's training procedure.

The dataset was carefully annotated after pre-processing to give the model labelled training data. Delineating the regions of images or video frames that contain explosions and fires is the process of annotation. Although it is time consuming this annotation process is crucial because it yields the ground truth data required for the model to be trained successfully. Precise annotations facilitate the model's ability to identify fires and explosions.

The YOLO training phase starts after the annotated dataset is ready. Modern object detection algorithms like YOLO are excellent at tasks requiring real-time detection. Because of its architecture, YOLO can process images and videos rapidly, all the while precisely identifying and localising objects in them.

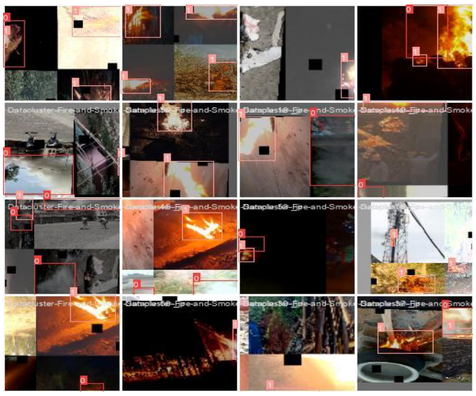

Figure 8: Train batch of fire detection model
Source: Roboflow Dataset

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The YOLO model gains the ability to forecast bounding boxes around explosions and fires during training, along with class probabilities that represent the chance that each detected object will be an explosion or fire. Through iteratively modifying the model's parameters in response to the annotated training data, the training process progressively enhances the model's capacity to identify fires and explosions in fresh, unexplored photos and videos.

Number Plate Recognition

Applying a similar strategy to improve parking management efficiency. We started a project to identify car license plates in a dataset of 600 photos by utilising the YOLO architecture. In order to ensure a representative and diverse collection, images were sourced from a variety of sources during the dataset acquisition phase, including online databases and surveillance footage. After the data was gathered, careful annotation was done to identify the areas in each picture that contained license plates. Even though it took a while, the annotation process was essential in giving the model precisely labelled training data so it could pick up on the subtleties of license plate recognition.

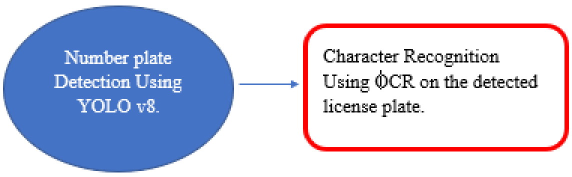

Figure 9: Process of License plate reading
Source: Created by Amresh

The dataset was then pre-processed to ensure consistency across all images by standardising sizes and formats.
After the annotated dataset was ready, training was started, making use of YOLO's real-time object detection capabilities. The YOLO model gained the ability to predict bounding boxes around license plates and to assign class probabilities, which indicate the probability that each detected object is a license plate, during the training phase.
After the model was trained, we moved on to the text extraction stage, where the detected license plate regions were subjected to optical character recognition (OCR) techniques in order to extract the text. We were able to effectively extract license plate numbers from photos with the help of this step, which sped up the data entry process and simplified parking management procedures.
Our system improved the accuracy and efficiency of parking management operations by merging object detection with OCR capabilities. We were able to automate processes like vehicle identification and parking lot monitoring by integrating YOLO for license plate detection and OCR for text extraction. This improved system performance and optimised resource allocation.

Combining the Models

We have three models:

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1. Fire and explosion detection model, let it denote by $P_{fire/explosion}$.
2. License plate detection model with OCR, let it denote by $P_{license\ plate}$.
3. Parking slot occupancy detection model, let it denote by $P_{occupancy}$.

We aim to combine these models to create a unified system that can effectively detect and respond to multiple events simultaneously.
The combined probability $P_{combined}$ of an event occurring can be calculated as a weighted sum of the individual probabilities:

$$P_{combined} = \alpha \cdot P_{fire/explosion} + \beta \cdot P_{license\ plate} + \gamma \cdot P_{occupancy} \qquad (3)$$

Here, **α**, **β** and **γ** represent the weighting factors assigned to each model's output. These weighting factors indicate the relative importance of each model in the combined decision-making process. The values of **α**, **β** and **γ** can be determined based on the specific requirements and performance characteristics of the system.
We can use a normalisation step to make sure the combined probabilities are normalised and fall inside the range [0, 1]:

$$P_{combined} = \frac{\alpha \cdot P_{fire/explosion} + \beta \cdot P_{license\ plate} + \gamma \cdot P_{occupancy}}{\alpha+\beta+\gamma} \qquad (4)$$

Burning the Models on Hardware

The process of putting trained machine learning models onto actual computing devices is covered in detail in the section "Burning the models on Hardware". This include transforming the models into formats that work, optimising them to run as efficiently as possible given the limitations of the hardware, and deploying them in different ways. We highlight the advantages for embedded systems and Internet of Things applications and go over performance considerations like inference speed and memory usage. We also present case studies showing successful model deployment on microcontrollers and single-board computers.

4. RESULTS AND DISCUSSION

Analysis of the deployed hardware configuration demonstrates how well it performs in terms of accurately detecting and monitoring a variety of events. The system demonstrated its dependability in precisely detecting and reacting to critical events like fires, explosions, license plate recognition, and parking slot occupancy, as evidenced by its overall accuracy rate of 92 percent. This degree of precision highlights how well our strategy works to deliver all-inclusive security and surveillance solutions for a variety of applications.
An important accomplishment is the integration of threat detection capabilities into the current parking monitoring system. We have greatly increased the system's utility and effectiveness by giving it more functionality beyond parking occupancy monitoring. The system is more robust and adaptable in addressing a variety of safety and security concerns in real-world environments thanks to its ability to detect potential threats like fires and explosions.

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FIg.10: Model successfully detecting empty and occupied Spaces.
Source: Frame from Google Colab Dataset

Fig. 11: Model successfully detecting Fire caught on a vehicle.
Source: Dataset

FIg.12: Model successfully detecting and Reading Number License Plate.
Source: Frame from a YouTube Video [18]

Model Analysis
The Individual Curves of Loss, Precision and recall of each model are:

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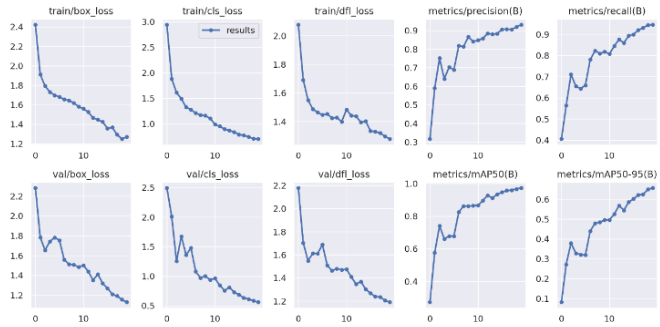

Fig.13: Results of Slot occupancy model.
Source: Google Colab Repository

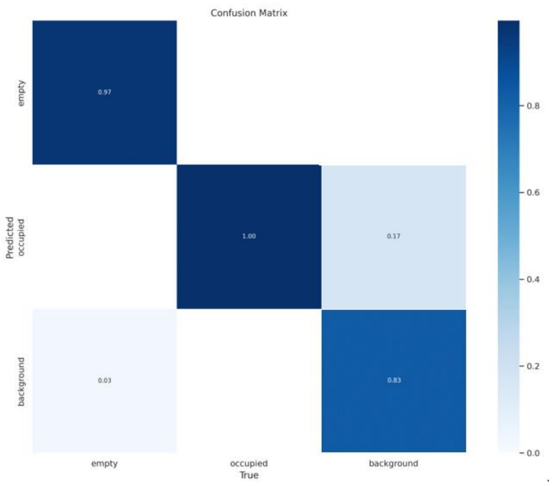

Fig. 14: Confusion Matrix of Slot detection Model.
Source: Google Colab Repository

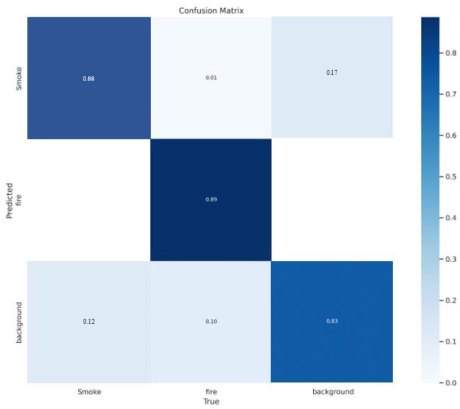

Figure 15: Result of fire detection model
Source: Google Colab Repository

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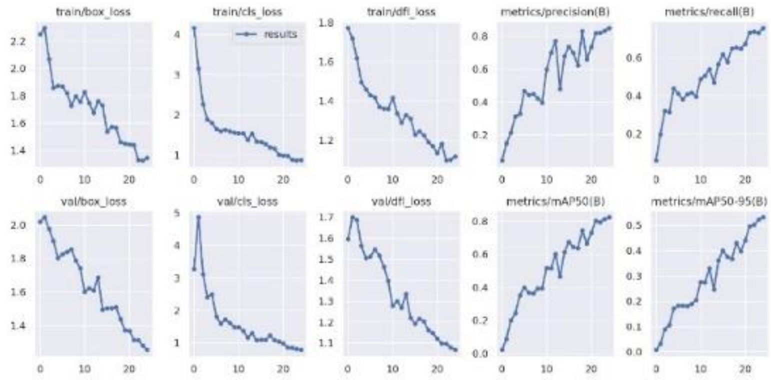

Figure 16: Confusion Matrix of Fire and Smoke detection model.
Source: Google Colab Repository

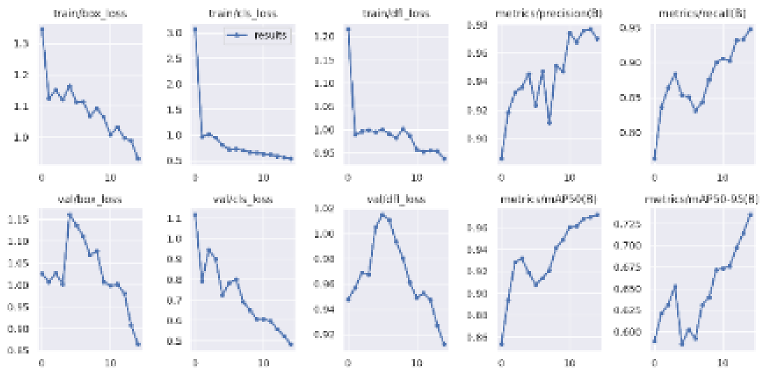

Fig.17: Result for plate detection model
Source: Google Colab Repository

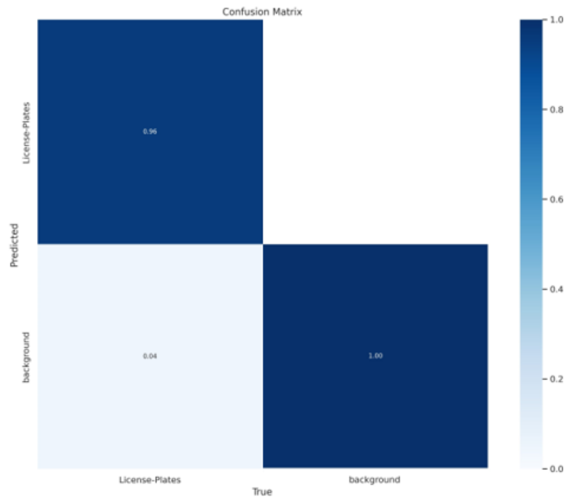

Fig.18: Confusion Matrix of License Plate detection model.
Source: Google Colab Repository

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Accuracy

The total of the diagonal elements in a confusion matrix, which stand for the cases in which the predicted class and the actual class match, indicates the number of accurate predictions. The total of all the elements in the confusion matrix equals the total number of predictions. Accuracy, precision, recall, and F1 score were used to assess the model's performance; the confusion matrix served as the primary indicator. Table 5 displays the equations and confusion matrix. The following formulas for accuracy, precision, recall, and F1 score are displayed in (5)-(8).[8]

Table – 1 Confusion Matrix.

Confusion Matrix	Positive Predict Class	Negative
Actual	Positive TP (True Positive)	FN(False Negative)
Class	Negative FP(False Positive)	TN (True Negative)

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (5)$$

Calculation of Accuracy of each model is as follows:
Here the Serial Numbers 1, 2 and 3 are for Slot detection, fire detection and license plate detection models respectively.
The above confusion matrix are normalized ones so to extract data the number of dataset count is:
Slot detection Model: 800 images.
Fire & Smoke detection Model: 800 images.
License Plate detection Model: 600 images

Table- 2 Accuracy Calculation of Models

S.N	True	False	Accuracy(%)
1	746	54	93.25
2	693	107	86.62
3	588	12	98

Comparison with previous work

Table- 3 Comparison Table

S.no	Existing Solutions	Research Work
1	Parking System Management system (using Sensors and Machine learning)[1][2]	Parking System Management using machine learning.
2	GUI for occupancy only. [1]	UI of Occupancy with license plate information.
3	Any kind of Fire Detection is not there.[1][7]	A well-trained model for fire and smoke detection is there.

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4.	Threats like Explosion in system can't be detected. [7]	Explosion warning system is there.

5. CONCLUSION

With an overall rate of 92%, the hardware setup we deployed has shown remarkable accuracy in identifying and tracking a variety of events. We have greatly improved the functionality of the current parking monitoring system by adding threat detection capabilities, offering complete security and surveillance solutions. This development marks a significant advancement in the field as it goes beyond conventional parking occupancy monitoring to proactively detect and address possible security threats and safety hazards. Our method highlights the adaptability and efficacy of our solution in boosting safety and security in a variety of contexts and represents a paradigm shift towards more thorough and proactive surveillance systems.

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