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AI Enabled Next-Generation Traffic Control System

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Abstract—Traffic is one of the superior problems in modern metropolis. Fresh and advanced technology related infusions are required to supervise themselves and direct traffic signals in order to decrease the snarl-upping of traffic. Major problem is when it comes to a predicament or an emergency circumstance which affects the servicing facilities like ambulances, fire trucks, police vans etc. In this paper, we capture data from the surveillance camera and using it we will train the machine using Machine Learning and Deep Learning. So, the process goes where we use a collective number of images which can be enormous in numbers which can be used to train the model. Subsequently, the vehicles are identified, and are categorized into various classes and this classification is done by itself, as it is edified to precision. We procured 88% accuracy using YOLOv5 for vehicle recognition. Further it contributes to the future, so that road design and scrutiny can be developed and secondly the fuel usage can be controlled, and the standby time is also saved effectively. Within some period, we will be able to harmonize most of the signals, by imparting a flexible traffic management system, thus resulting in declination of traffic congestion.

Keywords-Machine learning;Deep learning;harmonize;YOLOv5;CNN.

I. INTRODUCTION

All manuscripts must be in English. These guidelines include Traffic jam on road system is a cause where it includes soaring traffic, extended travel from one place to another and imperfect signaling system. The congestion on roads becomes more intense whenever there is a sharp increase in the aggregation of vehicles which is more than the road's occupancy. In the megalopolis atmosphere of India where the traffic snarl-up is higher, that it affects many factors of functioning of the country. There are some other reasons that cause traffic jams, they are poor space on roads and uncontrolled vehicle behaviors and inefficient application of traffic management systems. A serious issue is the overlong red-light and in some cases unawareness of roadblock and re-routing issues play their own role in causing road congestion. As in this thriving world, the importance of enhancement in creating ideas to solve this problem has risen. Nowadays, surveillance using camera is done. As we say that lengthy red signals are a showstopper, this is mainly caused due to inflexible coding for signal lights and analysis of the preliminary situations are imperfect. Predominantly traffic jams are caused as a consequence where occupancy of vehicles is higher than that of road capacity. So, in this paper we demonstrate how to regulate traffic congestion. It is feasible to identify the types of vehicles based on mass and measurements, and these details can be used to calculate traffic intensity. For instance, huge vehicles such as lorries(trucks) and buses occupy more area on the road than light weight vehicles like auto-rickshaws, cars, mini-vans and motorcycles, so they can contribute more to traffic density. One common mechanism to calculate traffic density by identifying the vehicle type is to use sensors that can segregate vehicles based on dimensions and mass. For instance, radar sensors or inductive loop detectors can be used to identify vehicles and classify them according to their size and weight. This can then be used to approximate the number of heavy vehicles moving through a specific point or area over a given time. The perfected data that is collected in advance and is produced to predict the traffic intensity at that time or within a period. A further approach is to use video cameras to capture images of passing vehicles and use image processing techniques to classify the vehicles based on their size and shape.

II. LITERATURE REVIEW

In the present era many young engineers are blooming with ideas to solve real time problems. One such problem is traffic regulations. Sabeen Javaid and et.al[1] system where there are mobile and web application for the reference of the officials who can have an exact idea of where traffic is present using RFID [Radio Frequency Identification]. In this system they are taking traffic density through cameras , sensor data. These RFID are meant for emergency vehicle, any unavoidable circumstances caused like fire accidents, smoke place etc., as these information are connected to the centralized servers the rescue department get immediate response from these systems.

Ninad Lanke and Sheetal Koul [2] proposed a system with a new technology where the whole system is dependent on the hardware called RFID [Radio Frequency Identification] which acts a boon to regulate traffic in real time. They have also used methods like inductive loop detection which are the insulated wires grounded below roads which detects a vehicle. They are using video analysis using cameras and infrared sensors.

Sheena Mariam Jacob and et.al [3] proposed a system for solving traffic congestion. The ideology of them are to divide the traffic into 3 main parts like high medium and low. These are classified with the RASPBERRY AI using ultrasonic sensors and cameras.

Fahimul Hoque Shubo [4] and et.al introduced some methodology for identifying the citizen who are making a traffic offence using computer based vision of YOLOv4 and OpenCV. The contemplated project uses DNN [deep neural networks] algorithm to find vehicles which did not follow the protocols proposed by the government. Here the image are classification is done for finding people riding without helmet, wrong direction, rash driving, traffic signal violation, unauthorized parking.

Jiachen Yang and et.al[5] proposed a system that works on the Modified Proximal Policy Optimisation (Modified PPO). It ideally suited as the scheme of software defined Internet of things(SD-IoT) for traffic control. It adjust the clip hyperparameter to limit the bound of the distance between the next policy and the current policy. Based on the collected data of SD-IoT, this system Controls traffic lights and vehicles in a global view to advance the performance of urban traffic control.This algorithm based on the deep reinforcement learning(DRL) and a imporivised version original PPO algorithm.

Junchen Jin and et.al[6] developed a adaptive signal control system which mimics and enhances professional signal control engineers' behaviors. It is a human-in-the-loop parallel learning framework which utilizes in an end-to-end recommendation sytem. The hyperparameters such as maximum and minimum green times varies in accordance with the traffic density. It utilizes various technologies, such as machine learning, data analytics, and cloud computing, to process and analyze large amounts of traffic data in real-time.

T. V. Janardhana Rao and et.al[7] suggested a paradigm to increase mobility by using roadside messaging devices. It is an IoT-based system that gather, analyse and store traffic data in real-time. This system was developed using machine learning algorithms such as neural networks and decision trees to process the data. It highlights the potential use of technologies to revolutionize and improve the quality of life of residents in urban.

Vikram Bali and et.al[8] proposed a IoT enabled technology by creating "Green Corridors" for emergency vehicles such as ambulances, fire-cars and also other vehicles. It is a smart and intelligent system to manage the traffic. It detects emergency vehicles by scanning the RFID tag applied on these vehicles using RFID reader. It helps vehicles to reach their destination in time. This paper provides a valuable overview of the current state of the art in intelligent traffic management systems and offers insights into the potential for future advancements in the field.

III. PROPOSED TRAFFIC CONTROL SYSTEM

This system aims to regulate the traffic congestion dynamically i.e. based on traffic density and traffic flow rate. It aims to improve traffic flow and reduce congestion on busy roads. This system computes length of time that a traffic signal should remain green based on the value of traffic density in the lane. It is computed by detecting and counting the number of vehicles by the image processing and object detection algorithms such as neural network architecture (YOLOv5) on the feeds from the camera of real-time traffic data. Based on the density values, system also make decisions about lane closures and traffic rerouting. The main objective of the project is to provide a safer and more efficient travel experience for drivers on the road.

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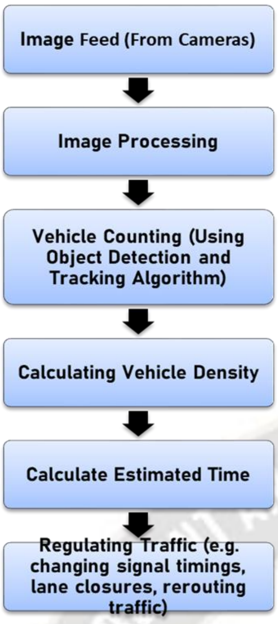

Figure 1 Pproposed Flowchart

Figure 1 depicts the work flow of the AI system which gets image as the feed and processes to get the vehicle count in that particular lane. This is further used to detect the traffic density which in turn makes the decision of the traffic regulations.

Dataset: The first step in this system is to prepare a dataset of images or video footage that includes different types of vehicles and traffic scenarios. This dataset will be used to train the vehicle detection model. The data is collected from the Dhaka-AI (A dataset in Kaggle).

For the image classification we have divided the vehicles to 21 classes as listed in Table 1.

TABLE 1 Classes

S.NO	Classes
1	Ambulance
2	army vehicle
3	auto rickshaw
4	Bicycle
5	Bus
6	Car
7	Garbage Van
8	human hauler
9	Minibus
10	Minivan
11	Motorbike
12	Pickup
13	police car
14	Rickshaw
15	Scooter
16	SUV
17	Taxi
18	three wheelers (CNG)
19	Truck
20	Van
21	Wheelbarrow

In table 1 all the classes which are determined in our deep learning model is used. Only with the help of the classes and labeling, our model is able to understand, train and validate it. We are using these type of split up not only to increase the accuracy and also to get the desired output. Using deep learning the major problem of people being stranded in roads even when there are less no of vehicle in other lanes are reduced to greater extent. We are also using cv2 & imghdr to process the images so that we have the same type (like 'jpeg','jpg','bmp','png') images are attained. All other type of images are also removed from our dataset.

The dataset needs to be pre-processed to remove any unwanted noise or artifacts which involve tasks like image resizing, normalization, and filtering. After pre-processing, the data need to be labeled by manually marking the location of each vehicle in each image or frame of the video footage. After labeling, Split the labeled dataset into training, validation, and testing sets for model development. The total data set is split for 2 reasons. One is for training and other one is for validating.

Figure 2 Without Annotation

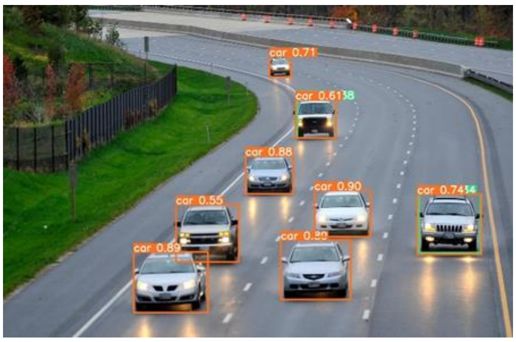

Figure 3 With Annotations

For training 70% of the total image is taken and 30% is used for validating. For testing the model separately some random images from web are which are not known or established to the model never before. With this kind splitting the model is made to train and validate more precisely and accuracy percentage is increased.

Randomly divide the labeled dataset into three subsets: training, validation, and testing.

Choose a ratio for each subset based on the size of the dataset and the complexity of the model. A common ratio is 60% for training, 20% for validation, and 20% for testing.

Ensure that the subsets are representative of the overall dataset in terms of the distribution of vehicle types and traffic scenarios.

Shuffle the images or frames within each subset to ensure that the model does not learn a bias based on the order of the data.Use the training set to optimize the model's parameters, the validation set to evaluate the model's performance during training, and the testing set to evaluate the final model's performance in real-world scenarios.

Model Development and Evaluation

A YOLOv5 model is trained to detect and count the different types of vehicles with the processed data. The images from dataset are segregated into batches (total of 16 batches) where each batch contain equal no of images. The batches are read by the model again and again with the help EPOCHS. The epochs are increased to get more accurate outputs.

Once the model is fit with train, epochs, validation data and callbacks it is made to run to calculate seconds per step, loss, accuracy loss, validation loss. At the last epoch the final accuracy is predicted. The dataset which are plotted with the help of AI plots to label are in xml format. The format are changed to text format and the boundary marks for the labeling is given in each of the text files.

After training the YOLOv5 model using the custom dataset, it is important to evaluate its performance on separate validation and testing datasets. The model gets validated using a validation dataset that was split from the original dataset during data pre-processing. To perform validation and testing in YOLOv5 “detect” function can be used. Then the model is evaluated by performance metrics such as precision, recall, and F1 score to know the model accuracy and precision.

Then the model is tested on a completely new dataset that it has never seen before. This is done to verify that the model can generalize well to new, unseen data. Based on the validation results, the model can be adjusted or fine-tuned to improve its performance.

Density Calculation

After the YOLOv5 model has detected the vehicles in an image or video frame, the next step is to calculate the vehicle density. This is typically done by using formulas that take into account the number of vehicles detected in the particular lane. It is calculated by dividing the number of vehicles and the width of the road .The density value varies with various factors such as the average vehicle length, and the spacing between vehicles. Vehicles are broadly categorized into 4 classes based on the size, weights, gross vehicle weight rating (GVWR) and its contribution to the traffic density.

The vehicles in these classes are as follows:

1) Light-duty vehicles: Bicycles and motorcycles generally fall under the category of light-duty vehicles, as they have a relatively low gross vehicle weight compared to other vehicles.
2) Medium-duty vehicles: The vehicles having GVWR less than or equal to 6000 pounds(2722 kg) which includes passenger cars, SUVs, pickup trucks, and vans. Light-duty vehicles typically have a smaller engine and are designed for personal use.
3) Heavy-duty vehicles:

Vehicles having a GVWR of more than 6,000 pounds (2,722 kg) which includes trucks, buses, and other commercial vehicles. These vehicles typically have a larger engine and are designed for commercial use.

Very heavy-duty trucks: Vehicles with a GVWR over 26,000 pounds (11,793 kg) which are used for hauling heavy loads or for commercial purposes.

Each class is assigned with a weight value as its contribution to the traffic density is not only based on no.of.vehicles and differs with each other.

Vehicle density = Σ (weight of the vehicle * no of vehicles) / width of the road

Once the vehicle density is calculated, the average density is computed by taking the mean of the densities with multiple frames of the video feed for precise density value.

The final step is to estimate the signal time, which is the length of time that a traffic signal should remain green in order to allow vehicles to pass through the intersection efficiently. The traffic flow rate is the number of vehicles passing through the intersection per unit time. The signal time is typically estimated based on the vehicle density and the traffic flow rate. The time is computed by considering the traffic flow rate of previous and upcoming two signals from that intersection .. The estimation of the signal time can be done using various algorithms such as fuzzy logic, neural networks, or rule-based methods. Once the signal time is estimated, it can be used to regulate traffic by controlling the traffic lights.

1) On-duty emergency vehicles

Our system can identify emergency vehicles by tracking the GPS signal they send to the system. Once the GPS is initiated, the system begins to track the vehicle's location in real time. The route taken by the emergency vehicle is cleared of traffic, allowing it to move freely towards its destination. This can cause some disruption to our system, as it is designed to detect and track all vehicles on the road. However, we have mechanisms in place to manage these interruptions and ensure the emergency vehicle can move unimpeded towards its destination.

2) Elite thoroughfare:

When VIPs visit our state, traffic must be adjusted to accommodate their movements. Our system plays a crucial role in managing traffic during VIP visits. As soon as the VIP convoy begins its journey, the traffic lights along their route are adjusted to ensure there is a sufficient level of safety for the VIPs. This allows members of the public to be aware of when and where road closures will occur. Our system plays an important role in keeping traffic flowing smoothly during VIP visits, while also ensuring the safety of all road users.

3) Driving against the designated flow:

Our system can detect vehicles that are driving in the wrong direction on the road by analyzing their movement. The system treats all the lanes as one-directional and marks any vehicles moving in the opposite direction as wrong way drivers. The driving direction on the road is predefined in our system, although it can be adjusted to accommodate the particular road being monitored. Our system tracks the movement of each vehicle along the x and y axes of the video frame to determine their change in position. This enables us to detect the direction in which vehicles are turning (x-axis) and moving forward (y-axis). By analyzing the changes in position along both axes, our system can identify when a vehicle is travelling in the wrong direction.

4) Rerouting:

When traffic congestion occurs, rerouting can be an effective strategy to reduce delays and minimize the impact on road users. Our system is equipped to analyze traffic patterns in real time with the help of image classification using DEEP LEARNING and provide suggested alternate routes to drivers. When our system detects congestion on a particular road, it can automatically suggest alternative routes to drivers. This can help to divert traffic away from congested areas and reduce delays for all road users. In some cases, rerouting can also be used to alleviate traffic in a particular area by encouraging drivers to use less busy roads. Our system can be a valuable tool for managing traffic in real time, making travel more efficient and less stressful for drivers.

5) Motorcyclists without head protection

Our system employs a four-step process to detect motorbike riders without helmets. First, all motorbikes and their riders are detected and classified in the video stream. Next, the area containing the motorbikes is isolated into individual images, which are fed into a YOLOv5-tiny model in step three. This model detects the presence of helmets on the riders in each image. If a helmet is not detected, the rider is marked in the video frame as a motorbike rider without a helmet. While this approach increases the time complexity of our system, we have found that using the YOLOv5-tiny model for helmet detection strikes a balance between speed and accuracy.

The first stage of our system is critical for accurately detecting traffic offenses, as it affects the precision with which vehicle positions and classes are logged and analyzed. To this end, we have trained and tested two models for vehicle detection and classification: a YOLOv5-tiny model, which achieved a mean average precision of 72.02% and a frame rate of 24-30 FPS on our setup; and a YOLOv5 model, which processed the video feed at 15-20 FPS.

6) Suspicious Vehicle Identification:

Vehicles which are not authorized to be in road at that particular point of time is detected. This is done when the image is sent to the YOLO V5 model and made for image processing. The rendered image detects the unauthorized vehicle with the help of our model. The stranded vehicles which are caught by CCTV camera are made into frames and processed.

7) Signal disregard

The Traffic signal is embedded with our system and it Scans the junction of the roads for the people who does not follow the traffic rules intentionally or not when the traffic light is in red. A visual marker at the intersection serves as a reference point for our system. If a vehicle passes over the marker while the traffic light is red, it will be recorded as a violation of the traffic signal. Once a vehicle has violated a traffic signal, it will be marked and remain so, even if it subsequently reverses.

IV. RESULTS AND CONCLUSION

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This model reduces the traffic drastically which can replaced for the conventional way of traffic movement. The main objective of developing this system is to minimize the waiting time on the road by optimizing traffic flow when there is no traffic on the other side. Moreover, the system also reduces assignment volume. In addition, the system addresses various traffic violations such as unauthorized parking, motorbike riders without helmets, rerouting, and providing a clear

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passageway for emergency vehicles by utilizing the technique of image classification.

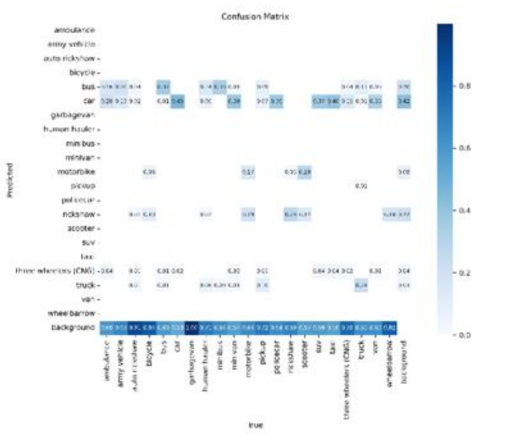

Figure 4 Confusion Matrix

The confusion matrix shows the summary of the prediction results on the Traffic Automation Problem. The number of correct and incorrect predictions are summarized. This is further broken into each classes.

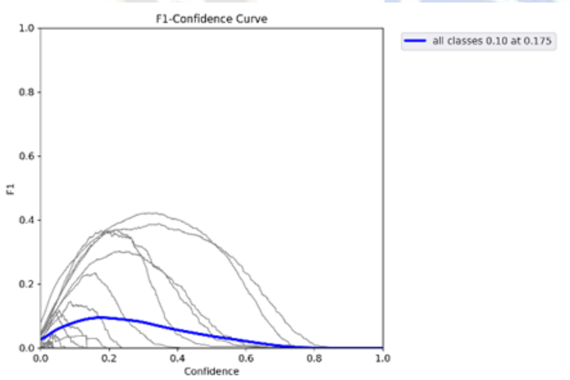

Figure 5 F1 Confidence Curve

Figure 5 is marked along the F1 and confidence for the data. This F1 is marked with taking into the consideration of Positive predictions and negative prediction which are in both classifier predictions and labeled training data. As per our confidence curve currently being implemented with 3000 images , which are broken into only 16 batches and with epochs has given the curve below 0.50. This will be increased when the no of images, epochs and batches are increased.

Figure 6 Classification Loss

In Figure 6, the classification loss has clearly depreciated from value greater than 0.70 to 0.50 approximately in just 3 epochs. The loss is being reduced a certain extent has the no. of epochs are very less. Since the runtime of the Model in deep learning is been very high the final accurate loss cannot be shown.

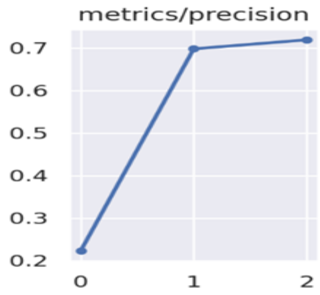

Figure 7. Metrics Precision Graph

Figure 7 shows the metrics precision which has the raised from 0.2 to 0.7. This metrics precision shows the no of correct positive predictions made. Even in the FIG 4.4 the precision can be increased to higher rates when prediction epochs are increased. It is calculated with the ratio of correctly predicted positive examples divided by the total number of positive examples that were used to predict.

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