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SMART TRAFFIC COP - URBAN CITY TRAFFIC VIOLATIONS DETECTION, REPORTING AND FINING SYSTEM BASED ON COMPUTER VISION

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Abstract— Sri Lanka has highly congested roads because of the rapid growth of vehicle ownership, the authorities' ineffectiveness in penalizing traffic offenses, poor road network maintenance, and less scrutiny of the driver's license application process. This negatively affects the country's health, well-being, and economic growth. The current traffic management system still heavily relies on a manual approach. In order to improve road safety, no platform integrates detecting traffic violations with a mechanism for issuing fines. Computer vision systems can significantly reduce traffic violations by tracking and penalizing traffic violations. The proposed approach was implemented using YOLOv5 object detection for traffic violation detections such as red-light runners, vehicle high speeding, and illegal lane changes. A results-focused facility requires computer vision to identify the vehicle and its number plate. Traffic law violations will be detected in real-time by the proposed system, which will report them to the traffic police to calculate dynamic fines based on the severity of the violation.

Keywords **- traffic violation, computer vision, red light runners, high speeding, illegal lane change, YOLOv5**

1. Introduction

Sri Lanka is rapidly urbanizing with the advancement of technology at a higher pace. Thus, the number of vehicles on the road have significantly increased over time. Hence this causes high volume of traffic resulting in road accidents, and traffic violations. To avoid these unfathomable consequences a centralized traffic violation detection, reporting and fining system is needed. Implementation of a real time system is critical as authorities track the roads every day to mitigate the increasing traffic violation crime rate. The standard way of penalizing traffic rule violators include traffic police to watch every passing vehicle in a designated area. The process itself takes time to process as such in the traditional way, traffic police officers would either confiscate the driver's license or penalize the driver then and there. The lengthy process of obtaining the driver's license back would take days. Therefore, to minimize this concern and to accelerate the process apart from mitigating human errors that might occur along the way, 'Smart Traffic Cop' serves the purpose of eliminating the exploited, long-established methods where law enforcement officers could take illicit traffic fines.

2. Background And Literature Survey

According to Sri Lankan traffic police data, 2419 people were killed in traffic accidents and 2325 fatal road accidents were reported throughout the year 2021. Among the killed are 697 pedestrians, 901 motorcyclists, 152 pillion riders, 243 drivers, 246 passengers, 184 cyclists and 14 others. In addition, 13,469 people were injured, 5,263 were seriously injured and another 8,216 sustained minor injuries [1]. Road accidents have thus become a significant issue in Sri Lanka as elsewhere. Road accidents in Sri Lanka have also become a major problem from the perspective of the transportation sector, negatively affecting the sustainable development of the nation and causing massive losses to the economy. In order to eliminate these fatal accidents as well as traffic violations that eventually lead to most of the road accidents, adapting to new technologies of road and traffic management is essential. Thus, the need for a system that is compatible in vehicle detection, red light, high speed, lane violation detection, and ANPR system that can be used to identify the vehicle owner to issue fines, fine management and problem solving is much needed.

2.1 Detecting Red Light Runners And Implementing A Dashboard For The Fining System

Overviews of existing systems show solutions in identifying red light runners and the factors that affect for red light violations. Based on the analysis of the Enduring Factors of Road Traffic Accidents in Sri Lanka, the authors suggest that reducing the number of vehicles used could be achieved by promoting public transportation and introducing strategic measures to manage transport demand [2]. Furthermore, the study proposes that policy makers may have to consider introducing awareness campaigns to enhance road safety, while imposing and enforcing rules and regulations in order to discourage and minimize unsafe driving practices and prevent the use of technically unsound vehicles, in view of minimizing road accidents in the long run.

Existing traffic violations systems have already been using different approaches of ANPR to identify number plates and the previous studies proves that it is necessary to capture the number plate of the vehicle and use this captured number to track the path of the vehicle [3]. Among these previously tested algorithms, Python and OpenCV are introduced as the best options to automate number plate detection system with traffic violations. In order to implement the proposed system, video footage from the planted cameras will be taken, and used for object detection, violation detection and number plate reorganization respectively. Previous studies had different approaches in detecting whether a vehicle is a red-light runner (RLR) or not. Several studies used estimation of speed in order to predict if the vehicle is a red-light runner. This is done by measuring in which the deceleration rate of the vehicle would be enough for it to stop before the violation line [4].

Dubai's Roads and Transport Authority (RTA) has launched a smart traffic controlling system in which a radar equipped with a camera, sensors, a transmitter-receiver, a data server, and a few electronic devices is used to recognize number plates, detect speed, and wrong U turns, unauthorized vehicles, and generate a fine with an attached violation picture. This study was essentially identical to a section of available technology in which two cameras were utilized, one at a high angle to identify the violation and the other at an eye angle to record a picture of a vehicle. The difference was that this was not done in real time. As a result, the future plan is to make it a reality [5].

In another research, they have only used video processing, where it does not require additional sensors to determine the traffic light status or to detect vehicles. Using only the video streams from a suite of IP cameras, the red-light system can detect vehicles violating the red light and can record all the evidence required for police officers to enforce traffic law by issuing electronic citations to the violators. To handle the multiple concurrent video streams, the red-light violation detection system spawns a separate process to handle each stream. Results of this method indicated that the second version of video analytics using YOLOv5's CNN as a detector and GoogleNet for the classifiers could handle visual uncertainties and yielded better accuracy, which relies on less robust classical image processing methods [6].

As mentioned above it is evident that the implementation of a robust, affordable, and an accurate traffic violation system is essential for a developing country like Sri Lanka. In our proposed method we will be tackling bottlenecks in the law enforcement offices in issuing fines as well as implementing a system to identify red light violations, illegal lane changes, and high speeding on par with a dynamic fine calculation system for road traffic violations which will then prevent unprecedented road accidents in the country.

2.2 Lane change violations detection and improving accuracy

The video is transformed into a collection of photos first. After that, a background is constructed using averaging, and the lane lines are retrieved using computer vision. To obtain complete and precise outlines of moving vehicles as well as lane lines, It is proposed to create a vehicle profile using background subtraction and edge detection. Identification of vehicles and lane lines are used to identify if a car is in the proper lane and, if not, to submit the occurrence to the fining system. Image/video recording and pre-processing can be used to detect illegal lane changes. Illegal lane detection can be easily discovered using the techniques above, and individuals who commit such infractions can face fines.

2.3 High speed violations detection

Most road accidents happen due to traffic rules violators. These accidents cause death, physical disabilities, and psychological disorders for people. Over-speeding is one of the leading causes of road accidents. Traditional systems of detecting and reporting speed-limit violations are not suitable for smart cities. The problem of speed-limit violation detection has been studied intensively for several decades. Traditionally, traffic patrols and speed radars have been used. Radar signals can be blocked or picked up by radar detectors, rendering them useless.

Many experts have studied the changes in traffic accidents throughout time, uncovering the risk variables that influence the occurrence of these dangerous events. According to research conducted by Mouyid and Kunnawee (2008) to identify variables in road accidents by in-depth accident analysis, road safety in Thailand was directly influenced by the rising trend of motorization, which was driven by the increase in Thai people's socioeconomic status [7]. They identified the primary risk factors of road accidents, such as faulty risk assessment and late evasive action, the lack of street-light facilities, and inadequate lane marking and visibility, which influence the severity of crashes and injuries.

From 1938 to 2013, Dharmaratne and Jayatilleke (2015) studied the trends in road traffic accidents, injuries, and fatalities in Sri Lanka [8]. They discovered that accidents fluctuated in lockstep with the country's political and economic progress and that the number of wrecks and injuries increased as the number of vehicles increased, while it decreased with stronger law enforcement and increasing use of public transportation. The alarming rate of vehicle ownership combined with inadequacies in road network development to support the demand for transportation were the most significant reasons for the increased number of road accidents in Sri Lanka, according to Somasundaraswaran (2006), who conducted a study using statistics from road accidents from 1989 to 2005[9].

2.4 Vehicle number plate detection using ANPR and accident prediction

ANPR has shown to be one of the most effective methods for vehicle surveillance. It can be used in a variety of public spaces for a variety of reasons, including traffic safety enforcement, automatic toll text collecting , car park system , and automatic vehicle parking system. We use this system to identify the mistakes made by vehicles and get the number plates details of those violators to identify the person behind the violation. The mistakes are referred to as illegal lane changes, red light violations and vehicle high speeding.

The four steps of an ANPR algorithm are as follows; capturing the image of the vehicle, number plate detection, character segmentation and recognition of characters. As illustrated in Figure 1 the first step, capturing an image of the car, appears to be a simple task, but it is rather difficult to capture an image of a moving vehicle in real time in such a way that none of the vehicle's components, particularly the vehicle number plate, is missing. Many systems now have number plate detection and recognition processing times of less than 50ms [10]. The effectiveness of the fourth step is determined by the ability of the second and third steps to locate the car number plate and separate each character.

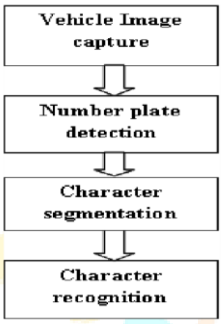

Figure 1: conventional ANPR system

In our modern society, rapid urbanization of countries is a huge step forward. Most people choose to live in cities rather than in rural areas. As traffic in these places grows, local governments frequently fail to anticipate residents' and tourists' current and projected transportation needs. The use of automatic number plate recognition (ANPR) to analyze the free flow of traffic is becoming more common, making intelligent transportation easier. Modern ANPR cameras can not only read license plates, but they can also provide vital information like counting, direction, vehicle model, color, brand, registered year, and speed. ANPR technology has found its way into many elements of today's digital world due to its capacity to recognize and interpret enormous volumes of fast-moving cars. While ANPR technology can be packaged in a variety of ways, they all serve the same basic purpose: to provide a highly accurate system for scanning a vehicle without the need for human intervention. It has a wide range of applications. There are four steps to extracting the number plates. Image processing, contouring and segmentation, character recognition and identification, and number plate recognition are the four categories. The photos of the retrieved number plates will be saved, and they have been categorized in Figure 2 and Figure 3

Figure 3: vehicle number plates of other countries

Figure 2: vehicle number plates in Sri Lanka

In severe weather, at any time of day or night, the system should be able to recognize number plates. Furthermore, the technology will detect any country license plates as well as filthy license plates. An inexpensive, low-resolution camera will be utilized in all implementations so that the system can be implemented at a low cost while still producing good accuracy. By matching the number plate with an existing dataset, the system determines the car owner's information, which is then transferred to the web-based interface for fining and reporting. Finally, using real-time data to train a machine learning model/ neural network to predict traffic violations, the updated dataset of data points related to traffic violations, such as vehicle number plate, vehicle size, speed, time of day, and weather, will be analyzed to predict traffic violations.

3. Research Methodology

This study aims to develop a system that can analyze and detecting road traffic law violations accurately and calculating fines based on the severity of the offence using computer vision and machine learning technologies. The accuracy of the system will be increased by training the models using datasets gathered from each node.

This system can be implemented near color lights or any road that has enforced lane change laws or speed limits. This can be implemented in a raspberry pi and a camera configuration called "nodes". Each of these nodes will have a mobile internet connection and can be configured to detect the following as per requirements of the location.

1. Red light violation detection
2. High speed detection
3. Illegal lane change detection

These nodes have two stages: Setup stage and Active Stage. In the setup stage, the node will gather data and footage required to identify violations more accurately. In the active stage, the nodes will actively process real-time footage and detect traffic law violations. If a violation is detected, screenshots and related metadata will be sent to a remote server for further processing and reporting.

3.1 Red Light Violation Detection

3.1.1 Functional Overview

The violation detection system has three operating modes.

- Training mode
- Region define mode
- Detection mode

Law enforcement officers will be able to set up and configure a computational unit with a camera at intersections with traffic lights to detect vehicles that cross the intersection stop line while the traffic light is red. After setting up the hardware, administrators can visit the web dashboard of the local computational node and start the "training mode" of the node. In this mode, the administrator can set a predefined region of interest to define the bounding box of the traffic light. This region of interest is used to capture frames required to train the color light identification model. Then the captured frames have to be grouped according to the color of the traffic light by the admin. This one-time training process will generate a model to later identify the color of the traffic light.

Next, the user is redirected to the "region define mode" to define the region of interest for the "violation zone". All region data is stored locally on the device. In the detection mode, if a vehicle enters the violation zone when the traffic light is red, it is identified as a violation. Frames related to this incident are saved on a cloud database along metadata related to the violation. Metadata includes the time duration it took between the light turning red and the violation occurring. This information can be used to calculate fines for the drivers. The web dashboard can then be used to view the violations and issue fines

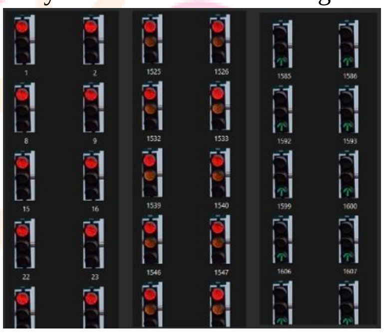

Figure 4: Captured traffic light images organized by color

3.1.2 Technologies Used

The backend and the primary processing of the system was implemented using python. For computer vision related processes such as loading the frames and preprocessing, we used the OpenCV library. Keras was used to define and train the neural network as well as image augmentation. SciKit Learn and Numpy libraries were used for dataset splitting and frame data handling respectively. As for the development of the local web server Flask was used. MongoDB was used as a remote database to store violations.

3.1.3 Image Processing

In the training mode, the user-separated traffic light images are used to train a convolutional neural network. First, the frames are imported and separated into training, testing and validation datasets. The split proportions are as shown in Figure 5.

```
x_train, x_test, y_train, y_test = train_test_split(images, image_index, test_size=test_r)
x_train, x_validation, y_train, y_validation = train_test_split(x_train, y_train, test_size=validation_r)
```

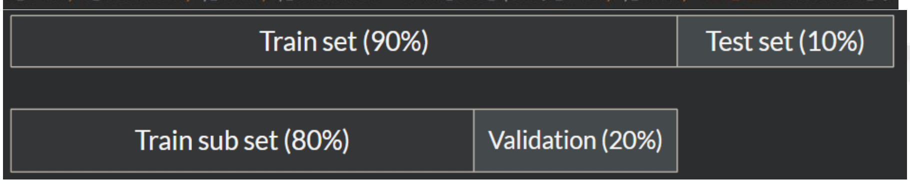

Figure 5: Train, test, split dataset proportions

After splitting the dataset, the frames are sent through a preprocessing stage. Each image is converted to grayscale and then the color histogram is normalized. This helps to reduce computational requirements needed to train the model, resulting in better performance.

```
def preProcessing(img):
    img = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
    img = cv2.equalizeHist(img)
    img = img / 255
    return img
```

Figure 6: Function to preprocess images

To improve the accuracy of the system, preprocessed frames are augmented to artificially create more training data. Image augmentation stage makes the following changes to each frame to generate more data using Keras' ImageDataGenerator function:

- Width shifting
- Height shifting
- Zoom
- Shearing
- Changing rotation

```
data_gen = ImageDataGenerator(width_shift_range=0.1,
                              height_shift_range=0.1,
                              zoom_range=0.2,
                              shear_range=0.1,
                              rotation_range=10)
```

Figure 7: Image augmentation method

3.1.4 Model Implementation

A sequential convolution neural network is used to train the model. After trying out multiple network shapes, we chose the following (Figure 8) 11-layer network shape which had the best performance and accuracy.

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 28, 28, 60)	1560
conv2d_1 (Conv2D)	(None, 24, 24, 60)	90060
max_pooling2d (MaxPooling2D)	(None, 12, 12, 60)	0
conv2d_2 (Conv2D)	(None, 10, 10, 30)	16230
conv2d_3 (Conv2D)	(None, 8, 8, 30)	8130
max_pooling2d_1 (MaxPooling2D)	(None, 4, 4, 30)	0
dropout (Dropout)	(None, 4, 4, 30)	0
flatten (Flatten)	(None, 480)	0
dense (Dense)	(None, 500)	240500
dropout_1 (Dropout)	(None, 500)	0
dense_1 (Dense)	(None, 3)	1503

Figure 8: Shape of the convolutional neural network

The training dataset is fed into the neural network to train the model. Then, the test dataset is used to measure the accuracy of the model, which yielded the following accuracy of over 95% as shown in Figure 9.

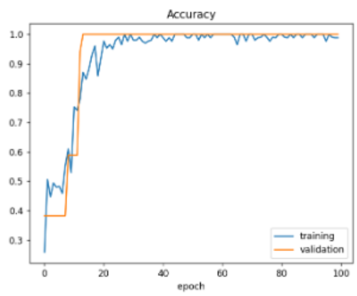

Figure 9: Accuracy of the model

3.1.5 Detecting Violators

In the "detection mode", we get a video feed from the camera (Figure 10) and use the violation region and traffic light regions defined in the earlier stages to crop the video section into two parts as shown in figure 11.

Figure 10: Input frame

Figure 11: Frame after splitting

Cropping and splitting the video feed reduces the load on the compute unit as it has fewer pixels in the frame for processing. The traffic light region is constantly being fed to the trained neural network to identify the color of the traffic light. When the traffic light is red, the violation region starts saving all the frames locally on the device. When the light turns green, the system will run an object detection process on the saved frames from the last “red light” period. This helps mitigate performance issues and avoid frame drops when doing this in real-time. The object detection is done using pre-trained YOLOv5 models. If the object detection process detects any vehicles crossing the violation zone when the red light is on, those frames will be saved locally as well as on a cloud database along with metadata such as time and date. Frames that do not have a violation will be deleted from the local device to save storage. These frames will be used by the ANPR system to identify the number plate of detected vehicles

This logic can be represented as follows:

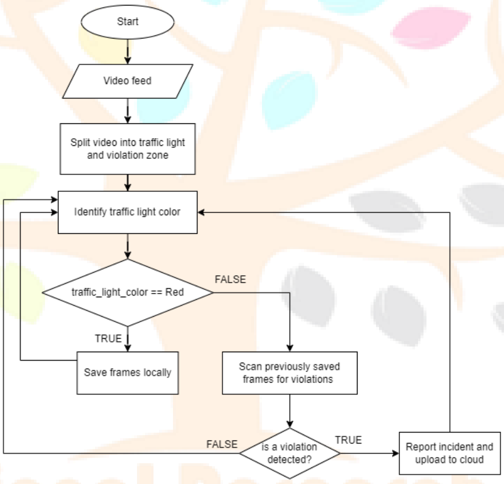

Figure 12: Red light violation detection logic

3.1.6 Web Interface

The web interface is designed to make it easier for the law enforcement officer to manage violations remotely.

Figure 13: Web interface home page

Figure 15: Red light detection interface

Figure 14: View violation

3.2 High Speed Detection

Vehicle high-speed detection is done once the video feed taken by the camera goes through the pre-processing stage. The video feed will be converted to frames and with the use of object detection vehicles in each frame will be uniquely identified. After that, the distance of each vehicle will be calculated by comparing two frames within the recorded footage. This will be used to calculate the speed of the vehicle. When the speed is calculated it is matched with the highest speed that the vehicle can be driven and if it is identified as a higher speed than the maximum speed limit it will be detected as a traffic rule violated vehicle.

The system is able to identify the vehicles that drive above the speed limit in bad weather conditions, daytime, and nighttime. Then the saved images of vehicles that have violated the speeding limit will be stored in the database and the results will be analyzed. Analytical details will be provided for future work. The system will analyze real-time footage and detect speed and trajectory anomalies to determine the probability of an accident happening. A dataset will be created and updated in real time. A machine learning model/neural network is trained using the created dataset. This can be used to identify reckless drivers. The system can also be able to identify accidents with a high detection rate and low false-alarm rate, in real time.

Figure 16: High speed detection interface

3.3 Illegal Lane Change Detection

We have set up cameras on traffic lights in selected areas to collect pictures and videos to identify the vehicle and number plate. The video is transformed into a collection of photos first. After that, a background is constructed using averaging, and the lane lines are retrieved using computer vision. To obtain complete and precise outlines of moving vehicles as well as lane lines, It is proposed to create a vehicle profile using background subtraction and edge detection. Identification of vehicles and lane lines are used to identify if a car is in the proper lane and, if not, to submit the occurrence to the fining system.

Figure 17: Illegal lane change detection interface

3.4 Automatic Number Plate Detection

When the images of violated vehicles are passed down by the previous components, those images will be saved in a database to extract the vehicle number plates. With the use of computer vision the number plate can be identified with high accuracy and also it will be used to get more details of the violated vehicles. Extraction of the number plates consists of four steps. The four technologies include image processing, contouring and segmentation, character recognition and identification, and number plate recognition. The images of the number plates gathered in this manner will subsequently be sorted and saved on a database.

Then the system is deployed in a manner even when in severe weather conditions or at any time of day or night, the system could be able to recognize number plates. An inexpensive, low-resolution camera will be utilized in all implementations so that the system can be implemented at a low cost while still producing good accuracy. By matching the number plate with an existing dataset, the system determines the vehicle owner's information, which is then transferred to the web-based interface for reporting and fining.

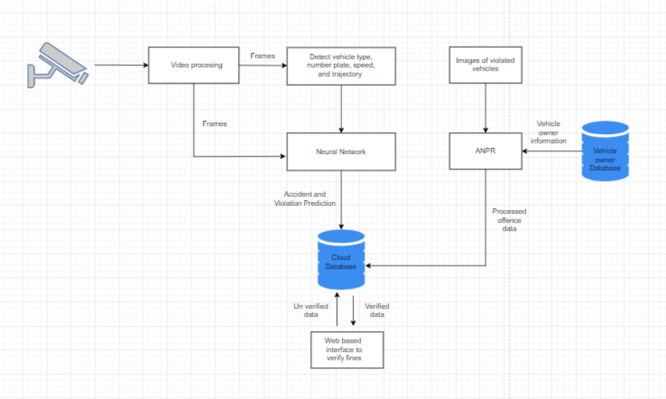

Figure 18: System Architecture for the number plate detection

4. Results and Discussion

During the requirement analysis phase of this research, several traffic police officers in the city of Panadura, Sri Lanka, were contacted to get their opinion on current bottlenecks and pain points in current traffic policing methodologies and techniques. In the current manual system, traffic police officers must spend a lot of time and energy identifying traffic violators. Another issue was not being able to detect violators when traffic police officers were not actively on duty. The proposed system can be used to mitigate these issues. In addition to the problems mentioned above, we also faced several technical challenges.

This system had to be designed in a way to reduce the computational requirements needed to compute computer vision technologies. For example, machine learning models can be trained using data specific to the traffic intersection on which it is being set up to narrow down the model and make processing faster and more accurate. Training models specific to an intersection and using camera data from various times and weather conditions allowed us to detect violations more accurately. The proposed system consists of a web dashboard that can be used to view and analyze the data recorded by local compute nodes. The web dashboard we designed to be a convenient portal to access data even with low technical experience.

Acknowledgment

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