Integrated Traffic Violations Detection System for the Highways of Bangladesh

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CERTIFICATE OF APPROVAL

The thesis titled, **“Integrated Traffic Violations Detection System for the Highways of Bangladesh**” is accepted as partial fulfillment of the requirement for the Degree of BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING of Islamic University of Technology (IUT).

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Declaration of Candidate

It is hereby declared that this thesis report is only submitted to the Electrical Engineering Department. Any part of it has not been submitted elsewhere for the award of any Degree or Diploma.

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Abstract

Effective traffic violation detection on highways is crucial for upholding traffic law and order, guaranteeing a smooth flow of traffic, and minimizing congestion and delays. The goal of this thesis is to create an integrated system for simultaneously identifying various traffic violations on Bangladeshi highways, with an emphasis on vehicles that aren't allowed to travel on them. To achieve greater accuracy in identifying offenders, the system combines various violation detection approaches and makes use of YOLOv8, the most recent version of YOLO. In this research, four traffic violations are detected, monitoring vehicles which are illegal on highways like CNG driven auto-rickshaws and easy-bikes, over-speeding, illegal road crossing on highways and wrong way driving. A new dataset containing images collected from the roads of Bangladesh were created for detecting illegal vehicles. For detecting the other three violations, YOLOv8 and its native tracker is used. The three violations viz wrong way driving, over-speeding and illegal road crossing detection systems were combined using a logical framework. The integrated traffic violations detection system performed with an accuracy of 95 percent which proves the efficiency of the system on Bangladeshi highways. This study provides an efficient integrated system for monitoring traffic violations on highways and serves a tool for the assistance of highway traffic authorities.

Chapter 1

Introduction

Traffic rule violations and their associated consequences have become a pressing concern for road safety and traffic management in Bangladesh. The country's highways, which serve as vital transportation arteries, are witnessing an alarming rise in incidents of reckless driving, over-speeding, illegal road-crossing, wrong way driving and other violations that jeopardize the well-being of commuters and contribute to traffic congestion. Addressing these issues and promoting responsible driving behavior demand innovative solutions that leverage the power of technology. This study aims to explore and propose an "Integrated Highway Traffic Violation Monitoring System Utilising YOLOv8" specifically designed for the unique characteristics and challenges of the Bangladeshi scenario.

The proposed integrated system harnesses the capabilities of computer vision, a subfield of ar- tificial intelligence, to monitor and detect traffic rule violations in real-time. By leveraging advanced image processing algorithms, pattern recognition techniques, and machine learning models, this system aims to simultaneously identify and document three types of violations: over-speeding, illegal road crossing, wrong way driving. It also focuses on to identify illegal vehicles like CNG driven auto-rickshaw and easy-bikes. The integrated traffic violations detection system is envisaged to operate through a network of strategically placed cameras and sensors, capturing relevant visual data and transmitting it for analysis and enforcement.

The context of Bangladesh presents unique challenges and requirements that necessitate the development of a tailored solution. Factors such as high traffic volume, diverse vehicle types, complex road conditions and variations in driving culture call for an integrated traffic violations detection system specifically designed to address the local scenario. This study seeks to delve into these challenges and develop an effective and efficient system that takes into account the distinct characteristics of Bangladeshi highways.

1.1 Problem Statement

Despite various efforts to enforce traffic rules and regulations, traffic rule violations remain a persistent issue on Bangladeshi highways, leading to a significant impact on road safety, traffic congestion and overall transportation efficiency. The lack of a comprehensive and technologically advanced system for monitoring and detecting violations in real-time poses challenges to effective enforcement, timely intervention and behavior modification among drivers. Furthermore, the unique characteristics of the Bangladeshi scenario, including high traffic volume, diverse vehicle types, complex road conditions and variations in driving culture, demand a tailored solution that can accurately and efficiently detect and document various types of traffic rule violations specific to the local context. Therefore, there is a critical need for an integrated highway traffic violation detection system that leverages computer vision technology to address these challenges and contribute to creating safer and more disciplined road conditions in Bangladesh.

1.1.1 Research Gap

Traffic violations have become a significant concern worldwide, with implications for road safety and traffic management. While various approaches have been proposed in the field of traffic violation detection, there exists a significant research gap in the exploration of a comprehensive and integrated approach that combines multiple violation detection techniques [1] While several studies have focused on individual violation detection techniques, such as wrong way vehicle detection, over-speeding detection, there is a lack of research on the integration of these techniques into a unified system.

Existing research predominantly investigates individual violation detection methods in isolation, without considering the potential benefits of combining different techniques [2]. However, an integrated approach that combines multiple violation detection techniques, such as over-speeding, wrong lane detection and jaywalking has the potential to provide more robust and accurate results in real-world scenarios. Moreover, the integration of these techniques with advanced computer vision algorithms, such as YOLOv8, has not been extensively explored. While YOLOv8 has shown remarkable performance in object detection tasks, its application specifically for the detection of some of the traffic violations like three-wheeler vehicle detection and the combination of multiple violation detection techniques is still a research gap that needs to be addressed [3].

By investigating the combination of different violation detection techniques and leveraging the capabilities of YOLOv8, this research aims to bridge the existing research gap and contribute to the development of a more comprehensive and accurate system for detecting various traffic violations. The proposed methodology will involve the simultaneous detection of multiple violations, enabling a more holistic approach to traffic violation monitoring.

Furthermore, the integration of these techniques and YOLOv8 will enable real-time violation detection. The combination of different violation detection techniques and their integration with YOLOv8 represents an unexplored research area in the field of traffic violation detection [4]. These research gaps are particularly evident in the context of Bangladesh. By addressing this research gap, this study aims to contribute to the development of a more comprehensive and efficient system for detecting and monitoring various traffic violations.

1.1.2 Problem Identification

Bangladeshi highways face a critical challenge in addressing traffic rule violations, which have adverse effects on road safety, traffic flow, and overall transportation efficiency. For this reason, the following things should be taken into account.

1. **High incidence of traffic rule violations** : Bangladeshi highways witness a significant number of traffic rule violations, including over-speeding, reckless driving, dangerous road crossing and banned vehicle such as CNG driven auto-rickshaw and easy-bikes driving. These violations contribute to an increased risk of accidents, congestion, and compromised road safety [5].

2. **Inadequate enforcement and monitoring**: The existing methods of traffic rule enforcement rely primarily on manual efforts, which are resource-intensive and prone to human error. The limited presence of law enforcement personnel hampers the effectiveness of enforcement measures, leading to a lack of deterrence and accountability for traffic rule violations [6].

3. **Unique challenges of the Bangladeshi scenario**: Bangladesh has its own set of challenges, including high traffic volume, diverse vehicle types, complex road conditions and variations in driving culture across different regions. These factors demand a systematic solution that considers the specific characteristics and requirements of the Bangladeshi scenario to effectively monitor and address traffic rule violations[7].

4. **Need for a technologically advanced solution**: With advancements in computer vision technology, there is an opportunity to leverage automated monitoring systems that utilize cameras, image processing algorithms, and machine learning models to detect and document traffic rule violations in real-time [8]. The lack of such a sophisticated and integrated system prevents the implementation of efficient and proactive measures

for traffic management and enforcement.

1.1.3 Research Question

For this work three research questions are formulated in connection with the three objectives. They are as follows:

1. Is it possible to combine major types of traffic violation monitoring algorithms into one single system?

2. Could it be viable implement a detection system for illegal vehicles by using a novel dataset obtained from important roads in Bangladesh?

3. Can YOLOv8 be used to improve the accuracy of existing traffic rule violation detection techniques?

1.1.4 Scopes

The research scope of this study focuses on developing an integrated Traffic Rule Violation Monitoring System (TRVMS) utilizing computer vision techniques for traffic monitoring. The primary objective is to detect and analyze various traffic violations in real-time using YOLOv8 which was tested on the footages taken from Dhaka-Mymensingh highway. The study aims to implement robust computer vision algorithms capable of identifying and classifying different types of traffic rule violations, such as over-speeding, wrong way driving and so on.

The monitoring system can be effectively implied in other highways of Bangladesh as well due to the fact that most of the highways face similar type of traffic violations. For instance, breaching the speed limit, driving in prohibited directions, pedestrians illegally crossing roads, banned vehicles plying on highways are all crimes that occur in other highways of the country. Hence, this system can be applied in other roads providing minimal modifications. Traffic violations like over-speeding and wrong way driving can also be detected with efficiently in highways abroad by optimizing the system's processing speed and efficiency to enable real-time detection and response to traffic violations. It may involve exploring parallel processing techniques, hardware acceleration, or optimization of computer vision algorithms to meet the stringent time requirements of highway monitoring scenarios.

To add to that, the drone videos used for testing the model were all from height adjacent to that of CC Cameras. Therefore, CCTV footage can also be maneuvered to detect these violations with the same efficiency.

Developing novel computer vision algorithms or improving existing ones for the accurate detection and recognition of traffic violations is feasible. It may involve exploring different approaches such as object detection, different tracking algorithms and classification algorithms specifically tailored for highway environments.

1.2 Objective

Aligned with the identified gap in the existing research, the identification of the problem, formulation of the research question, and establishment of the scope, the objectives of this study have been delineated with precise aims. These objectives are given below.

- To combine major types of traffic violation monitoring algorithms into one single system.

- To implement a detection system for illegal vehicles by using a novel dataset obtained from important roads in Bangladesh.

- To apply YOLOv8 model in traffic rule violation monitoring for better accuracy.

1.3 Research Outcome

The outcomes of this research endeavor are expected to be multifaceted and impactful. Firstly, the proposed system aims to enhance road safety by discouraging violations through its deterrent effect. The knowledge that their actions are being closely monitored can influence drivers to abide by traffic rules, reducing the risk of accidents and promoting a safer driving environment. Secondly, the system's ability to automatically capture and document violations will facilitate streamlined enforcement procedures, ensuring greater accountability and deterring repeat offenses. Furthermore, the data collected by the system can serve as a valuable resource for traffic analysis, enabling authorities to identify problem areas, prioritize interventions, and optimize traffic management strategies.

1.4 Research Significance and Motivation

The study holds significant importance in addressing the challenges associated with traffic rule violations on highways through the design and implementation of an integrated traffic violation detection system. The research objectives contribute to the field in the following ways:

First, this study aims to design a complete system capable of detecting traffic violations in real time and promptly reporting them to the relevant authorities. By leveraging computer vision technology and advanced algorithms, the proposed system will be able to accurately identify violations such including over-speeding, reckless driving, dangerous road crossing and illegal vehicle driving. The real-time reporting feature ensures that immediate action can be taken, leading to more efficient enforcement and a deterrent effect on drivers.

Second, the research involves creating a novel dataset that combines existing datasets with additional data suitable for training and evaluating the proposed system. By developing a comprehensive and diverse dataset specific to the Bangladeshi scenario, the study addresses the limitations of existing datasets and enables the system to handle the unique characteristics of traffic patterns, vehicle types, and driving behaviors in the country. This dataset creation process contributes to the development of robust and accurate models for traffic violation detection.

The significance of this research lies in its potential to enhance road safety, streamline enforcement efforts, and promote responsible driving behavior. By designing a complete system for real-time violation detection and reporting, the research aims to provide an effective tool for traffic management authorities to monitor and enforce traffic rules more efficiently. Additionally, the creation of a novel dataset tailored to the Bangladeshi scenario ensures that the proposed system can accurately capture and analyze violations specific to the local context, leading to more reliable and accurate detection results.

1.5 Research Methodology

• **Data Collection**: The research will begin by selecting MSCOCO dataset for the proposed integrated system. For illegal vehicle detection, UAV taken images will be used to train the custom YOLOv8 model. It has to be ensured that the dataset covers different weather conditions, lighting conditions, and traffic scenarios to make the system more robust.

• **Dataset Annotation**: The collected dataset will be annotated by labeling each illegal vehicle with bounding boxes. Annotation tools like CVAT will be used for this purpose.

• **Preprocessing**: The collected dataset will be then preprocessed by resizing the images and cropping for data augmentation to increase the size of dataset.

• **YOLOv8 Model Training**: YOLOv8 has to be trained for object detection model on the annotated dataset. YOLOv8 is a popular and powerful object detection algorithm that can efficiently detect and localize objects in real-time. The model is trained using a deep learning framework such as PyTorch, utilizing transfer learning by initializing the model with pre-trained weights on a large-scale dataset like COCO.

• **Model Optimization**: The YOLOv8 custom model will have to be fine-tuned and modeled for the specific highway traffic violation detection task like illegal vehicle detection using appropriate batch size and number of training iterations to achieve optimal performance. And finally regular evaluations on a validation set to monitor the model's progress will be conducted to preventover-fitting.

• **Integration with OpenCV**: The trained YOLOv8 model has to be integrated with the OpenCV computer vision library to create a complete integrated traffic violation monitoring system. OpenCV's video processing capabilities will be utilized to read and analyze traffic footage frame by frame. Then YOLOv8 model will be applied to each frame to detect and classify instances of traffic violations.

• **Violation Detection**: The logic will be implemented within the system to determine if a detected object corresponds to a traffic violation based on pre- defined rules and criteria. For example, thresholds for vehicle speed can be defined. If a violation is detected, The system will save the violation frame in a separate database.

• **Evaluation and Performance Metrics**: The performance of the custom trained model for detecting illegal vehicle will be evaluated by comparing the detection results against the ground truth annotations in the obtained dataset. Metrics like precision, recall will be used to assess the model's accuracy and effectiveness. Moreover, experiments to analyze the integrated system's robustness under various environmental conditions and traffic scenarios will be conducted.

• **Result Analysis**: The performance of the proposed system will be analyzed by identifying the number of correct and incorrect violation detections. The strengths and weaknesses of the YOLOv8 and OpenCV- based approach in terms of accuracy, speed, and resource requirements will further be discussed.

• **Real-world Testing and Deployment**: Real-world testing of the system will be conducted on highways or simulated environments to validate its practicality and reliability. The system's performance in real-time scenarios, gather feedback from users will be analyzed. Subsequently any potential limitations or areas for improvement will be identified [9-11].

1.6 Organization of the Thesis

The thesis at hand comprises seven chapters that explicate the theoretical underpinnings of the research, the data source, the analysis and interpretation of the findings, as well as the conclusion and implications of the research.

Following the introduction which mainly emphasizes on computer vision and its application, chapter 2 reviews the literature which covers the study past work on computer vision, three-wheeler detection, pothole detection, under speed and over speed detection and so on.

Chapter 3 provides overviews of the proposed model.

Chapter 4 represents the research methodology for the combined system to detect various violations simultaneously and adds the detailed information on the custom trained model to detect illegal vehicles.

Chapter 5 illustrates the result analysis of the research.

Finally, chapter 6 concludes the work. Limitations of the study are also discussed and recommendations for further research are presented in this chapter.

Chapter 2

Discussion on Related Works

In this section, the paper delves into the existing research and literature related to traffic violation detection using the YOLO (You Only Look Once) algorithm. Our focus is to explore the various studies and projects that have utilized YOLO for detecting different types of traffic violations. By examining these related works, the study aims to gain insights into the methodologies, findings, and advancements made in the field of traffic violation detection using YOLO.

Numerous research studies and practical implementations have leveraged the capabilities of YOLO for detecting and monitoring traffic violations. These violations may include over-speeding, wrong lane driving, red light violations, and more. The discussion encompasses a range of research papers, academic studies, and practical applications that have integrated YOLO into their traffic violation detection systems. Additionally, the research explores the performance evaluation metrics used to assess the effectiveness of YOLO-based traffic violation detection systems.

By examining the existing literature, the strengths and limitations of the YOLO versions before YOLOv8 can be identified and the potential of YOLOv8 for improving the accuracy, efficiency, and real-time capabilities of traffic violation detection systems. By exploring the methodologies, performance metrics, and advancements made in this area, this study aims to establish a solid foundation for our own research and identify opportunities to enhance the field of traffic violation detection using YOLO algorithm.

2.1 Computer Vision

Computer Vision is an area of artificial intelligence that focuses on teaching computers how to analyze and interpret visual data. It involves the creation of algorithms and procedures that enable machines to evaluate, process, and extract useful information from digital photos or videos. By recognizing and understanding objects, images, and patterns; computer vision systems aim to emulate human visual perception. These systems use a number of techniques and technologies to perform tasks such as image identification, object detection, facial recognition, image segmentation, and more. Computer vision has a wide range of applications, including medical imaging, surveillance, augmented reality, detecting objects and even entertainment. In this era, Computer Vision has become a quickly evolving field and a very important tool in healthcare, robotics, transportation, entertainment etc [12].

2.2 Traffic Violations in the highways of Bangladesh

Bangladesh is a country where many highways are being used regularly and those highways carry more vehicles than permitted in many occasions. Several traffic violations take place on those highways and in most of the cases, the traffic authority remains unaware of these incidents. The two main factors indicating the traffic violations of Bangladesh are, over-speeding in the highways and driving in the wrong direction willingly [13]. Other exclusive traffic violations of the highways of Bangladesh are, free movement of three-wheelers in the highways, potholes in several places of highways, pedestrians crossing the roads in an illegal manner, motor-bikers driving without helmets, unskilled drivers and reckless driving etc. Those traffic violations occurring in the highways of Bangladesh have to be reduced as soon as possible in order to prevent undesirable and fatal road accidents, to ensure proper traffic flow and to maintain an improved traffic management system. An integrated system is required which will detect those traffic violations of the Bangladeshi highways and report them immediately to the traffic authority.

2.3 Detecting Traffic Violations Using Computer Vision

The literature contains different methods of detecting different traffic violations using Computer Vision. In the related literature, the traffic violations being detected are illegal vehicles, wrong-way driving, over-speeding and illegal road-crossing. Several detection methods are being used in the literature and almost all of them show accurate results. Therefore, all of the methods are appropriate in detecting traffic violations. This thesis detects the aforementioned traffic violations using OpenCV library and Ultralytics YOLOv8 object detection and image segmentation model, which gives better performance than previous YOLO models.

2.4 Illegal Vehicles

Three-wheelers are a common mode of transport in Bangladesh. Rickshaws, vans, easy-bikes, CNGs those are the types of three-wheelers seen frequently in Bangladesh. These modes of transports are banned in the highways and treated as illegal vehicles. Though there are some strict restrictions in the usage of three-wheelers in highways, still many drivers tend to break the rules and restrictions and come out with their three-wheelers in the highways. This often leads to some dangerous road accidents in highways which have to be prevented. In the literature, there are some techniques and methods that focus on detecting those illegal vehicles. Some of the related works are as follows.

Rafi et al. (2022) [14] constructed a paper to detect three-wheeler vehicles using YOLOv5. Three different versions of YOLOv5 named YOLOv5l, YOLOv5m and YOLOv5s were used in the model to carry out the experiment of which YOLOv5l showed the highest accuracy. The dataset had different types of three-wheeler vehicles such as vans, easy-bikes and CNGs. However, it carried out the experiment for different classes of vehicles including those types of three-wheelers. On the other hand, in the proposed system, three-wheelers are being given importance solely and identified as illegal ve- hicles in the highways. And a novel dataset is being built taking drone images of CNGs and easy-bikes.

Mampilayil et al. (2019) [15] proposed a deep learning approach to detect three-wheeler vehicles and to identify the one-way traffic rule violation. Tensorflow along with OpenCV is being used to detect the three-wheeler vehicles. Since this method does not use any sensor, it is cost effective and readily deployable. Afterwards, R. M. Alamgir et al. (2022) [16] conducted a performance analysis of the different variants of the existing YOLO – architectures such as YOLOv3, YOLOv5s, YOLOv5x to detect the three-wheelers of which YOLOv5x outperformed the rest. Datasets were taken from the DhakaAI Dataset, Poribohon-BD Dataset and some self-collected images. However, in the present research, OpenCV library and custom YOLOv8 model has been used to detect the illegal vehicles such as CNG driven auto-rickshaw and Easy-bikes.

2.5 Wrong Way Driving

Driving in the wrong direction often leads to some terrible and horrific road accidents in the highways which results in severe mortalities in Bangladesh. It is always discouraged and prohibited to drive in the wrong way of highways. But, some drivers do this on purpose to reach to their destination quickly. In this way, road accidents take place on those occasions. This issue needs to be addressed as soon as possible and wrong way driving should be prevented at any cost. In the literature, there are several methods that give importance on detecting the wrong way driving of the highways. Some of the related works are as follows.

Z. Rahman et al. (2020) [17] discussed about an automatic wrong-way vehicle detection system from on-road surveillance camera footages. YOLO and Centroid Tracking Algorithm were used in this thesis to detect and track each vehicle driving in the wrong way. YOLOv3 and a deeper Convolutional Neural Network (CNN) was used to extract the features and COCO dataset was used to train the model. This model has some limitations with the Centroid Tracking Algorithm. However, in the proposed system, YOLOv8 and Native Tracker is used together to counterpart the limitations of Centroid Tracking and solve the issue. MS-COCO dataset is being implemented in this system. Higher accuracies are being generated by YOLOv8 and Native Tracker which results in successful detection.

P. Suttiponpisarn et al. (2021) [18] identified and detected wrong way driving using YOLOv4-tiny and Deep SORT Tracking Algorithm. The Region of Interest is taken into account for determining the vehicles which are driving in the wrong direction.

In the present research, Region of Interest (ROI) is also applied along with YOLOv8 with its native tracking algorithm. In this way, wrong way driving in the highways is being detected successfully and easily.

2.6 Pedestrians' Illegal Road Crossing

The illegal road crossing of pedestrians is a pretty common scenario in the highways of Bangladesh. As the pedestrians stay unaware of the possible outcomes that could possibly occur due to their illegal road crossing, fatalities and deaths are on the rise because of this. So, illegal road crossing of pedestrians should be stopped immediately and there should be some penalty for it. In the literature, there are several methods that focus on detecting pedestrians who cross roads illegally. Some of the related works are given below.

J. Park et al. (2019) [19] wrote a paper on detecting jaywalkers by using CNN (Convolutional Neural Network) where CNN classifiers are used for training purposes. BDD 100K and MS-COCO datasets were used in this model to train and test images for detecting jaywalkers. An accuracy of close to 96 percent was generated in this model. Later on, S. Mostafi et al. (2022) [20] used YOLOv4 and DeepSORT Tracking Algorithm to detect and track the jaywalkers. YOLOv4 and DeepSORT combined have a pretty great accuracy level which ensures proper detection of the jaywalkers.

This YOLOv4 model provides close to 97 percent accuracy which is great but in the proposed integrated system, Native Tracker and YOLOv8 are being added together to produce more accurate results. And a combined system is being constructed which can detect jaywalkers, wrong way driving and over-speeding vehicles together. This integrated system is ready to be applied on the highways of Bangladesh to detect various traffic violations including jaywalkers.

2.7 Over-speeding

Over-speeding is one of the main reasons behind disastrous road accidents in the highways of Bangladesh. As the highways are for high-speed vehicles, drivers tend to speed up more to overtake the vehicles in front of them. As a result, they lose control of vehicles and cause severe accidents. Over-speeding is natural to the drivers as they get excited when they see an empty road ahead of them. But the consequences are very alarming and shocking too. This has to be addressed on an immediate notice and legal actions have to be taken. In the literature, different methods focus on detecting the over-speed of vehicles. Some of the related works are as follows.

R. J. Franklin et al. (2020) [21] proposed a system implementing YOLOv3 and Convolutional Neural Network (CNN). MSCOCO Dataset was used in this case to carry out the training and testing. This YOLOv3 system had an accuracy of close to 92 percent for detecting vehicle speed. Afterwards, F. H. Shubho et al. (2021) [22] wrote a paper presenting a Computer Vision-based system for traffic offense detection. It was able to detect over-speed of vehicles, wrong way driving, unauthorized parking etc. The whole system was applied using OpenCV Deep Neural Network (DNN) Module. YOLOv4 and DeepSORT algorithm was used to detect and track vehicles in real-time. Accuracies close to more than 94 percent have been obtained in using YOLOv4 to detect the vehicles which are in over-speed.

In the proposed system, YOLOv8 with its Native Tracker Algorithm are being applied together to build an integrated system which can detect over-speeding along with wrong-way driving vehicles and jaywalkers of the highways. MS-COCO dataset is used in the model. This model provides outstanding accuracy level in detecting traffic violations which is a great milestone for the future.

2.8 Summary of the Chapter

The literature reviewed in this section leads to some major conclusions regarding traffic violation detection system in highways.

Firstly, two main factors are responsible for traffic violations in the highways of Bangladesh, speeding and wrong way driving. Illegal road crossing and illegal vehicles also cause problems in highways as they hinder the free movement of vehicles on the highways and expressways.

Second, traffic violation detection systems were developed previously using Convolutional Neural Networks, Haar Cascade Classifiers and different versions of YOLO including, YOLOv3, YOLOv4, YOLOv5 and YOLOv8 as the object detection algorithm. But a combination of these detection systems were not attempted in these works. Moreover, the SORT and Deep SORT algorithm was used as tracking algorithm in the traffic violation systems. But the use of the native tracker of YOLOv8 has much higher accuracy and consistency in tracking.

Another important part of the literature review done regarding traffic violation detection systems is that, in the existing literature, detection of vehicles which are prohibited to ply on the highways of Bangladesh is not done as a stand-alone task. In the proposed model, detection of unlawful vehicles including CNG driven autorickshaws and easy-bikes were done using a dataset created from images on the roads of Bangladesh.

In the next chapters, a model is developed on the basis of YOLOv8 and its native tracker to detect vehicles and pedestrians and suitable algorithms were developed to detect some of the traffic violations and to combine the detection systems.

Chapter 3

Proposed Model

The increased number of traffic offenses on roads, highways, and expressways makes it difficult for traditional methods of monitoring traffic offences to keep up. To address these issues, a novel strategy is brought up that makes use of computer vision to instantly identify and track various traffic infractions. The approach makes use of a network of strategically positioned cameras along highways and expressways to record real-time video footage of moving automobiles. The violation identification method, which uses the YOLO architecture to recognize and categorize numerous traffic offenses in real- time, then processes the acquired video feed. Thus, this strategy comprises of three basic parts: surveillance, real-time violation detection, offender identification, and actions taken by traffic authorities.

3.1 Surveillance

The suggested model includes a thorough surveillance system to ensure efficient monitoring of traffic offenses. To get clear video footage of the traffic flow, cameras are placed strategically along motorways and expressways. These cameras have a broad field of view, making it possible to observe cars and drivers on the road in great detail. The surveillance cameras have cutting-edge features including wide-angle lenses and high-resolution imagery. With the help of these technologies, the cameras will be able to take crisp, detailed pictures even in poor lighting and weather conditions. The cameras are placed at strategic points to cover multiple lanes, intersections, and critical areas prone to violations.

3.2 Real-time Violation Detection

In the proposed model, real-time violation detection is a pivotal component that leverages the power of the YOLO (You Only Look Once) algorithm. This algorithm excels in object detection and recognition, enabling swift and accurate identification of various types of traffic violations. YOLO algorithm is trained beforehand to detect the following traffic violations:

a) Illegal vehicles
b) Illegal road crossing
c) Wrong way driving
d) Over-speeding

As the live video footage from the surveillance cameras is fed into the system, the YOLO algorithm analyzes each frame in real time. The YOLO algorithm first detects the objects of interest for the model, including cars, passer-by and illegal vehicles. Since the detection of illegal vehicles requires the use of object detection only, the YOLO algorithm detects the objects and flags them as traffic violations. For the other violations, such as, over-speeding, under-speeding, illegal crossing of roads and wrong lane usage, the YOLO algorithm first detects the cars and people. Then the model performs other logical operations including performing calculation of speed and point-polygon test to detect the violations [23]. It detects and highlights instances of violations, including over-speeding, under-speeding, crossing of roads, wrong lane usage and illegal vehicle violations.

3.3 Offender Identification

In the proposed model, the component of offender identification focuses on capturing and storing the frame of the footage in which the violation occurred, along with their respective time and date information. This enables traffic authorities to access concrete evidence and take appropriate actions against the violators. When a violation is detected by the real-time detection system, the model captures an image of the offending vehicle. This image, which serves as visual evidence, is securely stored in a dedicated database. The database maintains a record of all the captured images, associating them with the relevant time and date of the traffic violation.

Chapter 4

Methodology

4.1 Data Collection

MSCOCO dataset was used for detecting wrong way driving, over-speed detection and illegal road crossing detection.

COCO (Common Objects in Context) is a large-scale collection for finding and describing objects. COCO has several features: object segmentation, recognition in context, super pixel stuff segmentation, 330K pictures (¿200K labeled), 1.5 million object instances, 80 object categories, 91 stuff categories, 5 captions per image, and 250,000 people with key points [24]. The COCO dataset is extensively used for training and evaluating deep learning models in object detection (including YOLO, Faster R-CNN, and SSD), instance segmentation (including Mask R-CNN), and key point detection (including OpenPose).

For illegal vehicle detection, DJI Mavic Air2s drone was used to capture images of illegal vehicles like CNG driven auto-rickshaw and Easy-bike from different roads to create a novel dataset.

4.2 Detection Algorithm

In our proposed model, we have employed the YOLO (You Only Look Once) algorithm for object detection, which has demonstrated remarkable performance in various computer vision tasks. With its exceptional speed and accuracy, YOLO has gained significant popularity and has become a prominent solution for real-time object detection tasks. Unlike traditional object detection methods that rely on complex pipelines and multiple stages, YOLO presents a unified framework that delivers impressive performance with remarkable efficiency.

4.2.1 Justification of Choosing YOLO for Object Detection

The YOLO (You Only Look Once) algorithm offers several key advantages that make it a compelling choice for object detection in real-time applications.

First, because of its regression-based methodology, YOLO runs extremely quickly. YOLO does away with the requirement for intricate processing pipelines by framing detection as a regression problem. In the tests, YOLO runs with amazing speed, a faster version of which may run at over 150 frames per second while using a Titan X GPU without batch processing. Because of its incredible speed, YOLO can process streaming video in real time with a latency of under 25 milliseconds. Additionally, YOLO outperforms other real-time systems by attaining more than double the mean average precision, guaranteeing precise and effective detection.

Second, YOLO differs from sliding window and region proposal-based algorithms in that it can reason globally about the entire image. YOLO thoroughly examines the entire image during both training and testing, allowing it to implicitly encode contextual information about classes and their look. This broad logic ensures that YOLO takes into account the wider context and considerably lowers the amount of background errors. Comparatively, advanced identification techniques like Fast R-CNN, which cannot view the complete image, frequently misidentify background patches as objects. Global perspective of YOLO improves accuracy and reduces false detections.

Thirdly, YOLO demonstrates great generalization skills. Leading detection techniques like DPM and R-CNN are significantly outperformed by YOLO when trained on natural photos and tested on artistic work. This capacity to generalize is a key benefit because it enables YOLO to continue performing well even when used in newdomains or with unexpected inputs. YOLO demonstrates its versatility and robustness in a variety of applications by learning representations that are portable across numerous image domains.

4.2.2 How YOLO Works

Before delving into the details of the YOLO algorithm, it is essential to briefly mention some other popular object detection algorithms. The R-CNN (Region-based Convolutional Neural Network), Fast R-CNN, and Faster R-CNN are additional popular object detection methods. Regions of interest (ROIs) are often formed as part of these algorithms' two-step procedure, which is followed by their classification and refinement [25-27].

The YOLO method, in comparison, adopts a different strategy by conducting object categorization and region suggestion in a single pass. Because of its amazing real-time performance and one-shot detection capability, YOLO is an excellent choice for our suggested real-time violation detection system.

YOLO consists of a convolutional neural network (CNN) that processes the input image and generates bounding box predictions along with class probabilities. The CNN typically follows the architecture of a pre-trained classification network, such as Darknet or ResNet, which has been adapted for object detection. The core idea of YOLO is to simultaneously forecast bounding boxes and class probabilities using a single convolutional neural network (CNN). By taking a more comprehensive approach, YOLO is intrinsically faster and more effective than two-step algorithms. YOLO drastically decreases computational complexity and delivers near real-time performance without sacrificing accuracy by doing away with the requirement for region proposal techniques.

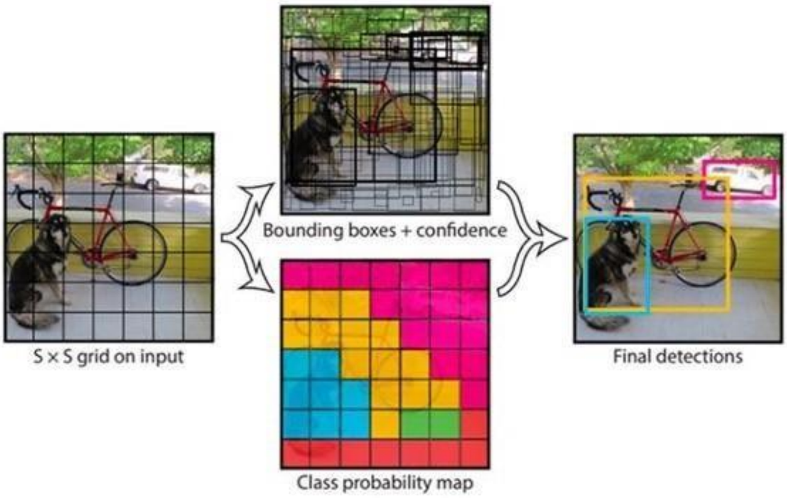

Figure 4.1: YOLO working methodology

YOLO algorithm divides the input image into a grid of cells. The size of the grid can vary depending on the specific YOLO version or configuration. Each cell is responsible for predicting bounding boxes and class probabilities for objects present within its boundaries. To make it easier to find objects with varying sizes and aspect ratios, YOLO uses anchor boxes. As the algorithm is trained, these anchor boxes serve as reference templates that it can later modify. Multiple anchor boxes are predicted by each grid cell and correspond to various item sizes and forms. YOLO forecasts bounding boxes within each grid cell in relation to the cell's location. The top-left corner, width, and height coordinates of each bounding box make up its four values. Regression is used by YOLO to forecast these values, enabling precise object localization. For each bounding box, YOLO also forecasts class probabilities, which show the chance that the object belongs to a variety of predefined classes [28].

The specific dataset and application determine the number of predicted class probabilities. To ensure that the predicted class probabilities for each box add up to 1, YOLO uses softmax activation.In addition to bounding boxes and class probabilities, YOLO assigns a confidence score to each prediction. The confidence score represents the algorithm's confidence in the presence of an object within the bounding box. It reflects both the accuracy of localization and the confidence in the assigned class probabilities.

Non-maximum suppression (NMS), a post-processing technique, is used by YOLO after producing bounding box predictions. To make sure that each object is represented by a single, most reliable bounding box, NMS removes overlapping and unnecessary bounding boxes. Based on the confidence scores, it eliminates low-confidence detections and keeps just the ones that are the most pertinent. The bounding boxes, associated class labels, and confidence scores for the discovered objects make up the YOLO algo- rithm's final output. Usually, this data is displayed as a list of objects, each of which is identified by its coordinates, class label, and confidence level.

YOLO algorithm uses the Intersection over Union (IOU) metric to assess the degree to which predicted bounding boxes and ground truth annotations coincide. The non-maximum suppression (NMS) step and loss function of YOLO both depend heavily on IOU.IOU calculates the ratio of the intersection area to the union area of two bounding boxes to determine the amount of overlap between them. It gives a measurement of how well the predicted bounding box resembles the annotation from the ground truth. A better alignment and a more precise detection are indicated by a greater IOU.

Figure 4.2: Intersection Over Union used in YOLO

The YOLO algorithm's impressive performance is evident in its superior mean average precision (mAP) compared to other real-time object detection systems. It achieves excellent detection accuracy while maintaining remarkable processing speeds, making it an ideal choice for applications that require both efficiency and precision.

4.2.3 Reason of choosing YOLOv8

Performance-wise, YOLOv8 offers a huge improvement over earlier iterations. It features architectural upgrades and algorithmic upgrades, improving detection precision and processing performance. YOLOv8 is also recognized for its incredible speed, which makes it very effective for tasks requiring real-time object detection. Additionally, YOLOv8 has undergone comprehensive training and evaluation on a variety of datasets, demonstrating its generalizability and resilience across a range of object detection settings [29].

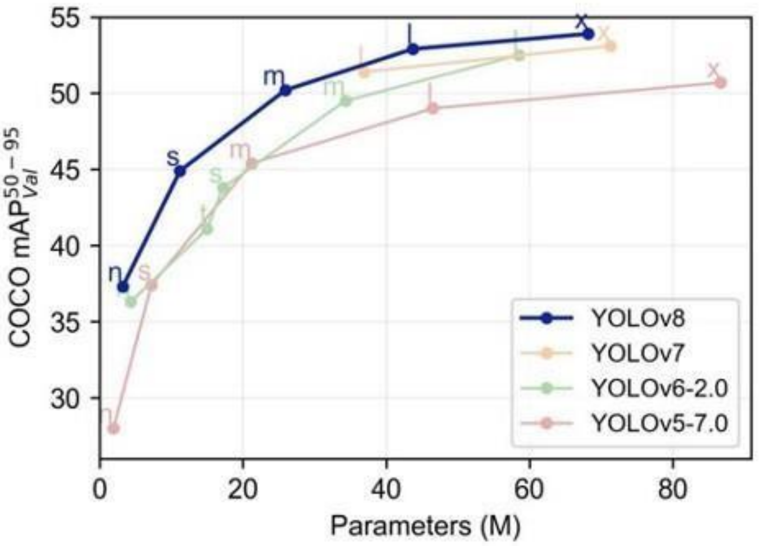

Figure 4.3: Comparison of different versions of YOLO

4.3 Tracking Algorithm

The native tracker built into the YOLOv8 method that was used as the tracking algorithm for the detection systems is presented in this section. In order to keep object tracking consistent and continuous across successive frames, the tracking algorithm is essential.

A deep appearance model and a basic online tracking algorithm are thefoundations of the native tracker in YOLOv8. The tracker can discern and follow detected items even in difficult situations like occlusions and changes in scale and direction because the appearance model captures the visual characteristics of the identified objects.

The native tracker in YOLOv8 makes use of effective online tracking methods and the capabilities of deep learning to deliver reliable and precise tracking of objects between frames. The tracker can deal with a variety of difficulties that arise in real-world situations by including appearance modeling and occlusion handling.

Tracking plays a pivotal role in this work as it is one of the main components of the traffic violation detection system. The continuity and consistency of tracking for all detected vehicles was ensured by integrating the native tracker within YOLOv8. It is essential to provide the vehicles individual identification numbers since it enables precisely associating and following their motions across successive frames.By using these identifiers as a point of reference, each vehicle's behavior and movements can be tracked during the whole video recording. By assigning distinctive identifiers to the identified objects in the first frame, YOLOv8's native tracker creates its initial state. These identifiers act as a guide for following the objects in later frames.

Utilizing the native tracker in YOLOv8 allows seamless interaction between object identification and tracking operations, allowing us to track traffic offenses completely and precisely. Analyzing the behavior and movement patterns of violating cars requires the tracker to be able to maintain object identity and track continuity.

YOLOv8's tracking algorithm, which helps to track and evaluate traffic violations in a dynamic, real-time environment, is an essential part of all violation detections. Its effectiveness and efficiency serve the overall goals of our research by helping to reliably detect and monitor traffic offenses.

4.4 Violation Detection

The study contains a solution to detect wrong way driving, pedestrian road crossing, three-wheeler and over speeding on the highway of Bangladesh. The working principles are described below for each type of violation.

4.4.1 Wrong Way Driving Detection

In a country like Bangladesh, people frequently drive the wrong way down the road. Therefore, a prompt detection is necessary in order to avoid potentially fatal accidents.

An innovative algorithm for identifying drivers going the wrong way has been proposed in this model.

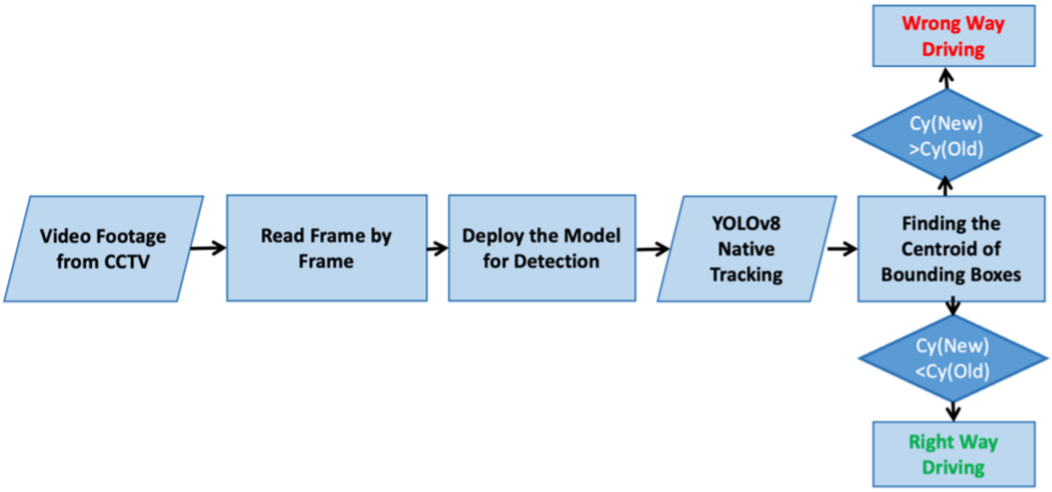

Figure 4.4: Flowchart of wrong way detection

First, the video footage was read frame by frame using cv2.VideoCapture and cap.read() function of OpenCV. The pre-trained YOLOv8n model is applied to each frame of the video to detect and localize vehicles. This process generates bounding box coordinates for the detected objects. After that using the bounding boxes' x1, y1, x2, and y2 coordinates, the centroid coordinates of the bounding boxes were determined. To give each vehicle a one-of-a-kind identifier, YOLOv8 native tracker was used.

By selecting two appropriate areas which represents the two lanes of a highway and using point PolygonTest function, the vehicles whose centroid is located within the chosen area were identified.

After that, the centroid coordinates for each unique id were stored in two different dictionaries for two different lanes that were kept separate from one another. Whenever a new vehicle enters into the chosen area, then it's assigned id is checked in the dictionaries. If the dictionaries don't contain the id, then the id is assigned as key and corresponding centroid coordinates are assigned as value in the corresponding dictionary.

The y coordinate of the centroid either increases or decreases compared to its value in the frame before it, and this change relies on the direction the vehicle is traveling.

This allows us to specify a condition that must be met in order to find automobiles that are traveling in the wrong direction.

So, vehicles that are traveling in the incorrect direction can be found in any lane of the highway by comparing the y coordinate of the centroid to the value it had in the previous frame.

4.4.2 Pedestrian Illegal Road Crossing Detection

People are frequently observed crossing highways in an unauthorized manner, which not only puts them in danger but also puts other drivers in danger.

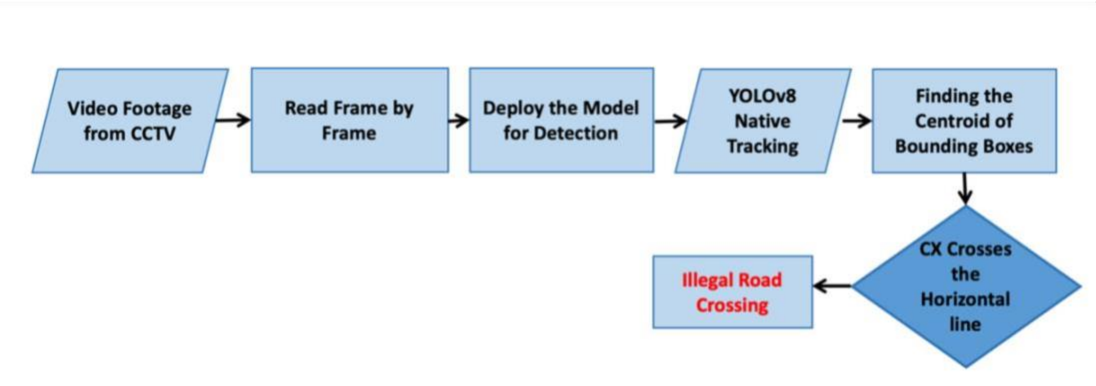

Figure 4.5: Flowchart of illegal road crossing detection

Therefore, in order to recognize pedestrians walking down the middle of the road, the video footage was read frame by frame using cv2.VideoCapture and cap.read() function of OpenCV.The pre-trained YOLOv8n model is applied to each frame of the video to detect and localize pedestrians. This process generates bounding box coordinates and using the bounding boxes' x1, y1, x2, and y2 coordinates, the centroid coordinates were determined.A horizontal line was drawn to find cases of unlawful road crossing on highways.

For each detected pedestrian, their centroid coordinates are checked to determine if the x coordinate of the centroid, Cx crosses the horizontal line. If a pedestrian is found to cross the horizontal line, it indicates a potential case of illegal road crossing.

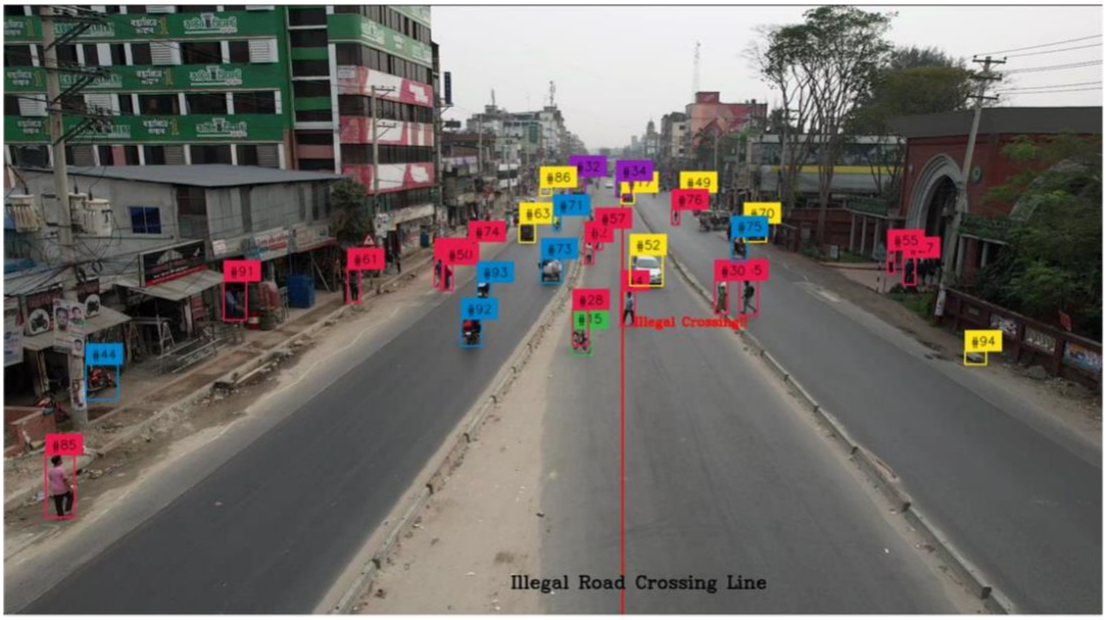

Figure 4.6: Horizontal Line for Detecting Illegal Road Crossing

4.4.3 Over-speeding Detection

Road safety, traffic control, and the strict adherence to speed limits all depend on the accurate detection and monitoring of vehicle speeds. Speeding is a frequent traffic infraction that increases the risk of accidents and has serious repercussions for both vehicles and pedestrians. Over-speeding increases the risk of accidents in highways. Over-speeding events are addressed in the suggested method for speed detection.

In the speed detection technique, the video frames captured by the surveillance cameras are fed into the YOLOv8 model for vehicle detection. The model analyzes each frame and identifies vehicles by predicting bounding box coordinates and associated class probabilities.The frame's Region of Interest (ROI) is then defined. The ROI is a particular area where vehicle detection accuracy is known to be high. Usually, it is determined by things like the camera angle, the distance from the road, and the visibility of the area. Based on the particular needs of the monitoring area, the ROI's specified range is set. Usually, it is designed to capture a specific stretch of highway or road. The distance might be calculated based on recognized physical landmarks or estimated based on the field of view of the camera.

The time at which a vehicle enters the specified ROI is noted using time.time() function. Similar to this, the vehicle's exit time is recorded when it leaves the ROI. These timestamps document the exact seconds when the vehicle enters and leaves the des-

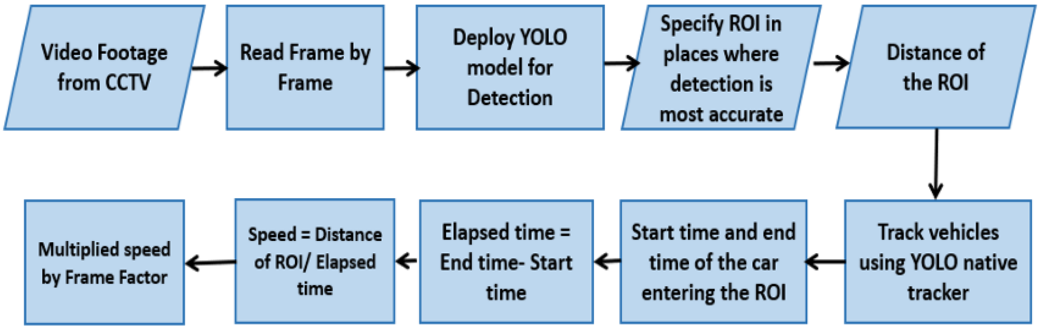

Figure 4.7: Flowchart of Over-speed Detection

ignated area. The total time needed for the vehicle to travel the ROI is computed by deducting the entry time from the departure time. The time it took the vehicle to travel the predetermined distance inside the ROI is represented by this duration. The average speed of the vehicle is determined using the ROI's distance and travel time. By dividing the distance by the time, one can calculate the speed. The result of this calculation is the vehicle's average speed across the designated ROI.

The speed limit of that specific highway is set beforehand in the model, according to the speed limit fixed by the traffic authority. If the average speed of the vehicle is found to be greater than the speed limit, it is flagged as over-speed offender.

4.4.4 Illegal Vehicle Detection

Despite the fact that driving CNG driven auto-rickshaw and Easy-bike on highways is illegal, people still do it all the time, which leads to a significant number of deadly incidents. So, a system should be introduced to detect these illegal vehicles.

Image Collection and Augmentation

DJI Mavic Air2s drone was used to capture images of illegal vehicles like CNG driven auto-rickshaw and Easy-bike from different roads to create a novel dataset. These images are taken at different times of a day with various lighting conditions. A total no. of 247 images were captured. These images were cropped horizontally to remove background noise. Then each of the images were cropped vertically to generate more images. Using such data augmentation techniques, the dataset was increased to almost twice its' size.

Annotation and Labelling

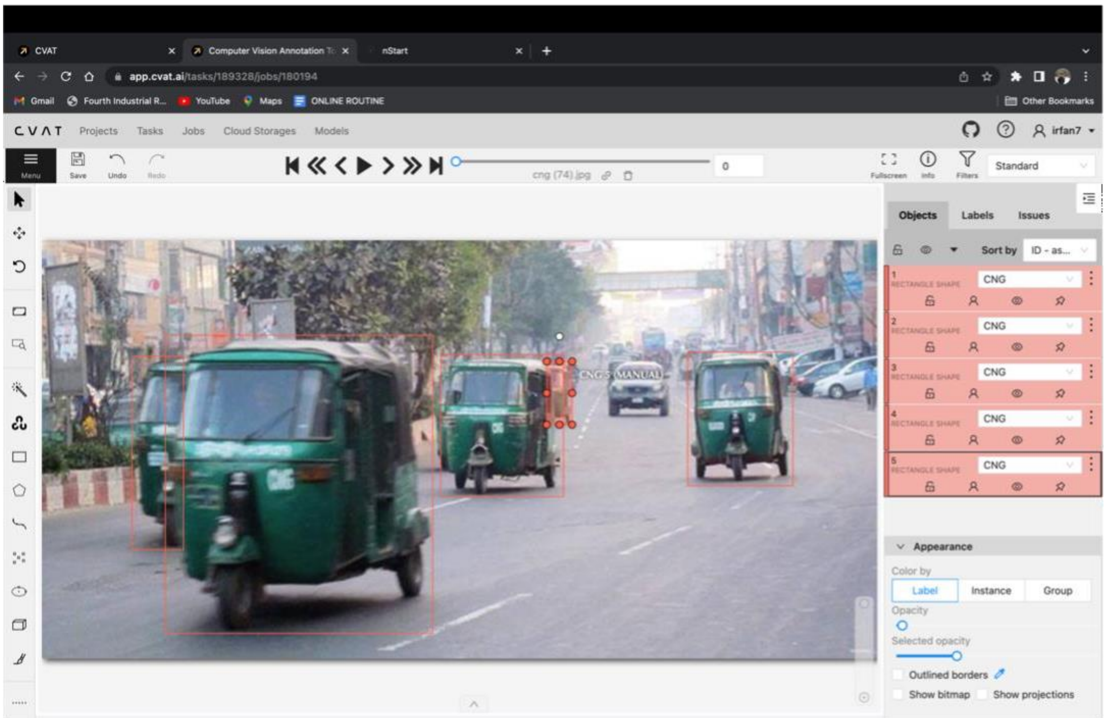

Figure 4.8: Labelling Illegal vehicles using CVAT

CVAT (Computer Vision Annotation Tool) website was used for annotation and labelling.This website provides assistance in designing bounding boxes for objects and the class labels associated with those boxes. After finding the objects, drawing the bounding boxes around them, and labelling them, a zip file containing all of these labels is downloaded, and the validation and train sets of labels are retrieved from it. The YAML file contains the label name and the path to the data of the images that were used for training and validation. Using Google Colaboratory, a custom model was trained using 50 epochs.

Overall Process

For the detection of illegal vehicles,the video footage from the closed-circuit television camera was read one frame at a time using cv2.VideoCapture and cap.read() function of OpenCV. Illegal vehicle detection is then handled by the customized YOLO model. The model identifies illegal vehicles and shows bounding box around it. To give each vehicle a one-of-a-kind identifier, YOLOv8 native tracker was used.

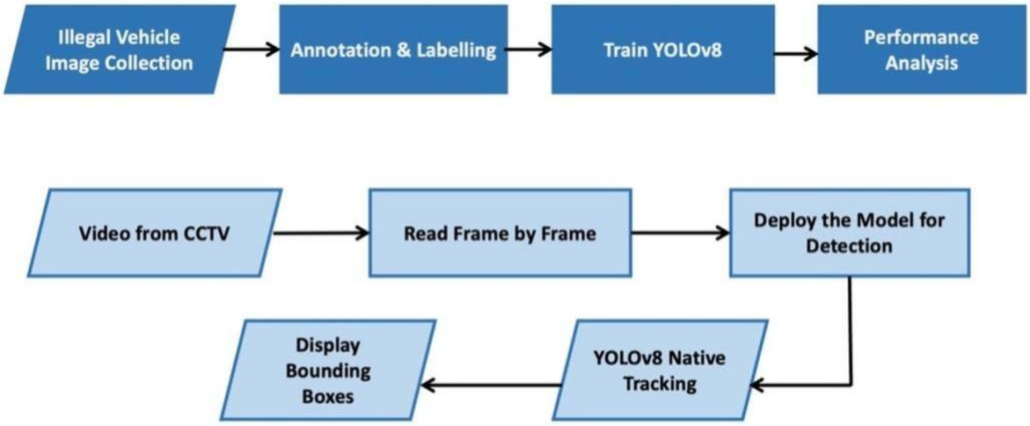

Figure 4.9: Flowchart for Illegal Vehicle Detection

4.5 Combined System

Numerous efforts have been undertaken in the past to identify numerous traffic violations, such as: driving in the wrong direction detection, driving at an unsafe speed detection, illegal road crossing detection, etc. However, it should go without saying that every detection algorithm should function simultaneously in order to make any traffic infraction monitoring system as effective as possible. The proposed approach performs exceptionally well in this respect.

The proposed system can simultaneously detect drivers who are going the wrong way on the road, unlawful road crossings, as well as those who are going too fast or too slow. The mechanism for identifying these three different kinds of violations has already been covered in sections 4.4.1, 4.4.2, and 4.4.3, respectively.A logical framework has been developed that empowers the detection and classification of multiple types of violations simultaneously.By utilizing YOLO's object detection capabilities, vehicles of interest, such as cars, buses, motorbikes, and trucks can be idetified. By analyzing the class names of these detected vehicles, the dedicated algorithm for identify instances of wrong way driving or speeding were employed.To detect illegal road crossing, logic for checking the class name "Person" was defined from YOLOv8 detections and if the classname matches the algorithm for illegal road crossing was employed.

In this way, these three detection algorithms have been meticulously combined in

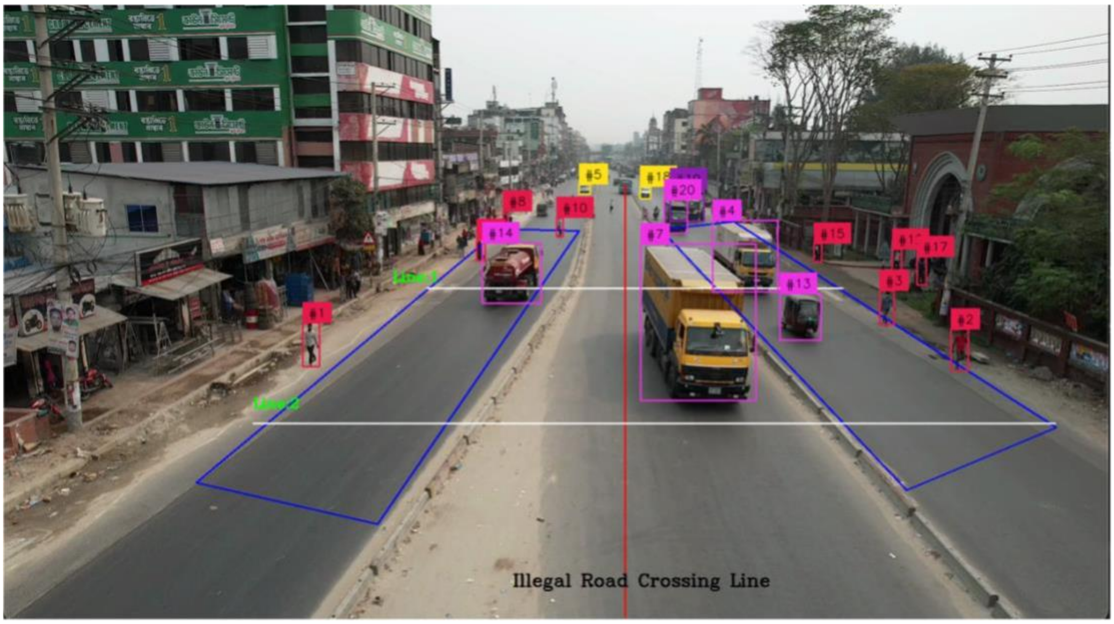

Figure 4.10: Combined System for detecting major traffic violations

the system that has been proposed in order to make the system more reliable and effective, and as a result, the system is now able to detect three of the most serious types of traffic offences. In addition, the proposed system will record the frames in which a violation is found and save them in a separate database. This will allow the authorities in charge of traffic control to use the data as a reference and take the appropriate legal action against the driver who broke the law.

4.6 Traffic Violation Database Creation

It is essential to develop a thorough database that collects the pertinent data related to each infraction in order to permit effective monitoring and analysis of traffic offenses. This section outlines the methods and processes used to build a reliable traffic violation database. The proposed system will record the frames in which a violation is found and save them in a separate database. This will allow the authorities in charge of traffic control to use the data as a reference and take the appropriate legal action against the driver who broke the law. When a violation is found, the system timestamp is used to extract the appropriate frame from the video stream. A secure database is then used to retain the extracted frame, which serves as visual proof of the violation, together with the time and date of the infringement.

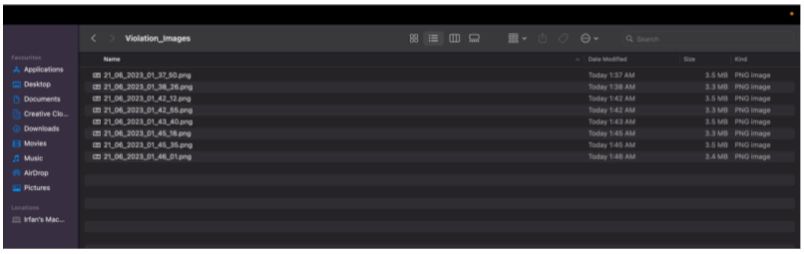

Figure 4.11: Database for Storing Traffic Violating Frames

Figure 4.12: Sample frame of over-speeding from the database

Chapter 5

Result Analysis

The experimental results were conducted on a machine with a unified memory of 16GB having Apple M1 Pro chip, 8-core CPU with 6 performance cores, 2 efficiency cores, 14-core GPU, 16-core Neural Engine and 200GB/s memory bandwidth with a SSD of 512GB. The programs are written in Python3.9 with the help of various libraries like OpenCV, NumPy, Math, OS, Time etc.

The videos for the live testing were captured using DJI Mavic Air2s which can take 5.4K video at 24 FPS. The drone captured live footage without hindrance at 12 feet from ground level.

5.1 Object Detection Metrices

The Average Precision (AP), sometimes known as the Mean Average Precision (mAP), is a standard measure of an object detection model's performance. It's a single number that may be used to assess the relative accuracy of various models across all domains.

5.1.1 mAP

The mAP metric is based on precision-recall metrics, can deal with more than one type of object, and uses Intersection over Union (IoU) to define a positiveprediction.

Precision and Recall

Precision measures the accuracy of the model's positive predictions, whereas recall measures the proportion of actual positive cases correctly identified by the model. Precision and recall are typically mutually exclusive. In order to account for this trade-off, the mAP metric integrates the precision-recall curve, which plots precision against recall for various confidence thresholds. By evaluating the area under the precision-recall curve, this metric provides a balanced evaluation of precision and recall.

Handling Multiple Object Categories

Multiple item types in an image must be located and identified by object detection models. The mAP metric calculates the average precision (mAP) for each category separately before averaging these mAPs for all categories.

Intersection Over Union (IoU)

Object detection tries to figure out where things are in a picture by guessing their bounding boxes. The Intersection over Union (IoU) measure is used in the mAPmetric to judge how good the projected bounding boxes are. IoU is the ratio of the area where the projected bounding box and the ground truth bounding box meet to the area where the two boxes meet.

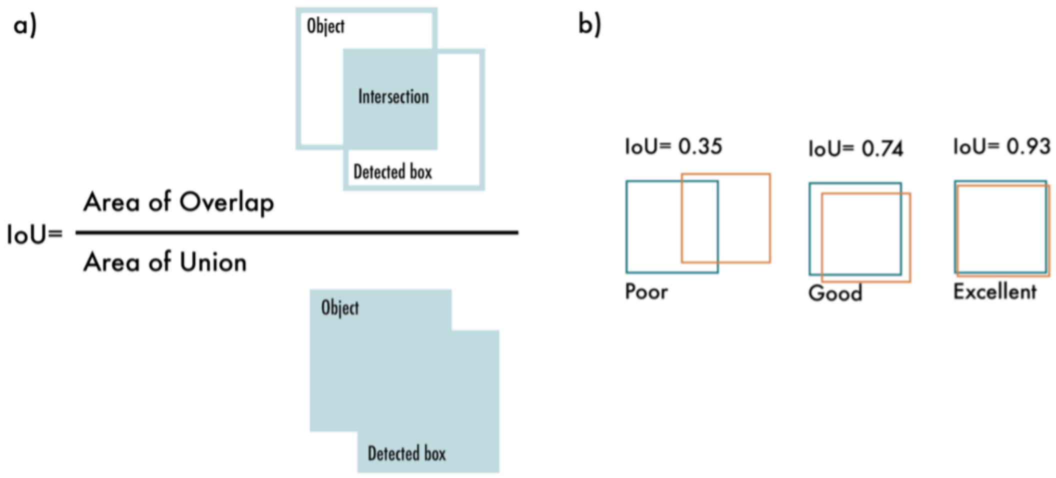

Figure 5.1: Intersection Over Union

5.1.2 Calculating mAP

Accuracy-recall curve's area under the curve has to computed to get the average precision for each class. By comparing precision values to comparable recall values at various confidence score thresholds, this curve is produced. Finally, by averaging the AP values across all classes, Mean Average Precision (mAP) can be determined.

5.2 Combined System Performance

The integrated system for the identification of traffic offences, which includes illegal road crossing, speeding, and driving the wrong way on one-way streets, produced encouraging results in accurately identifying and highlighting potential offences. To test the performance of the proposed system, a video of Dhaka-Mymensingh highway in front of Islamic University of Technology was taken. In this section, the overall performance of the system is evaluated as well as the findings that were acquired for each specific violation detection are given.

When it came to identifying cases of illegal road crossing, the system displayed an impressive degree of accuracy. It repeatedly found persons crossing the street in inappropriate places.

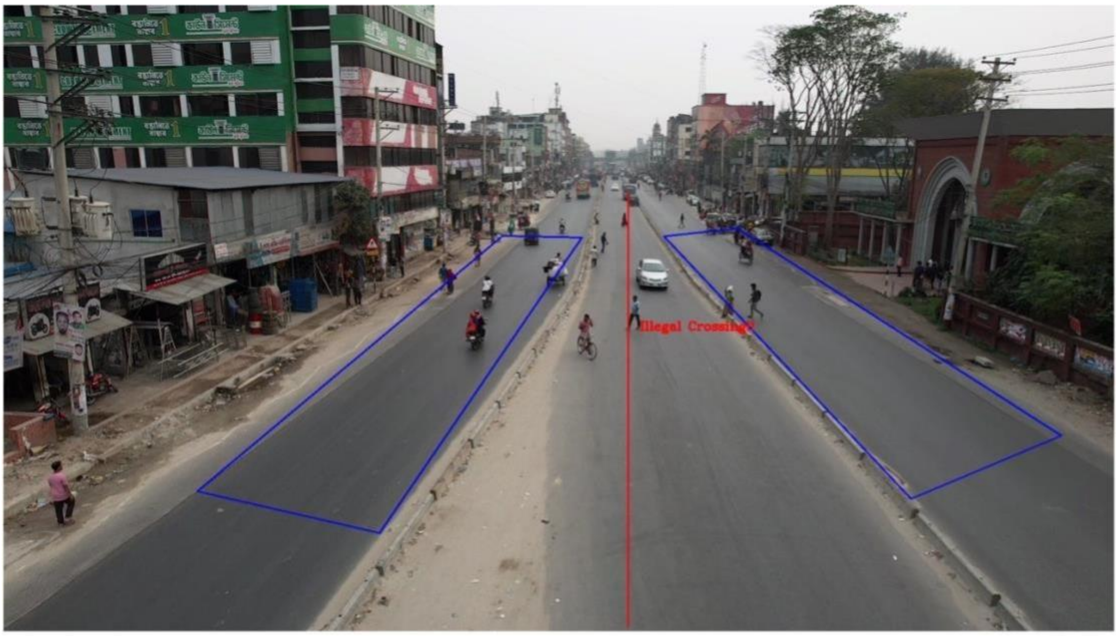

Figure 5.2: Performance of Illegal road crossing detection

The high detection accuracy implies that the system is able to recognize human presence and differentiate it from other objects that are present inside the video frames. This enables the system to identify illegal road crossings in a manner that is both efficient and dependable.

The algorithm was able to identify vehicles that exceeded the predefined speed limit of 50 km/hr threshold by doing an analysis of the velocities of vehicles contained within the video frames. However, this algorithm totally depends on the frames per second (FPS) of system while processing the output. So, a frame factor is used to multiply with the calculated speed in order to get approximately accurate result. The original video is 24.09 FPS. However, the system processed it in 2.5 FPS. So, a frame factor of 24.09/2.5 = 9.67 is used in this test.

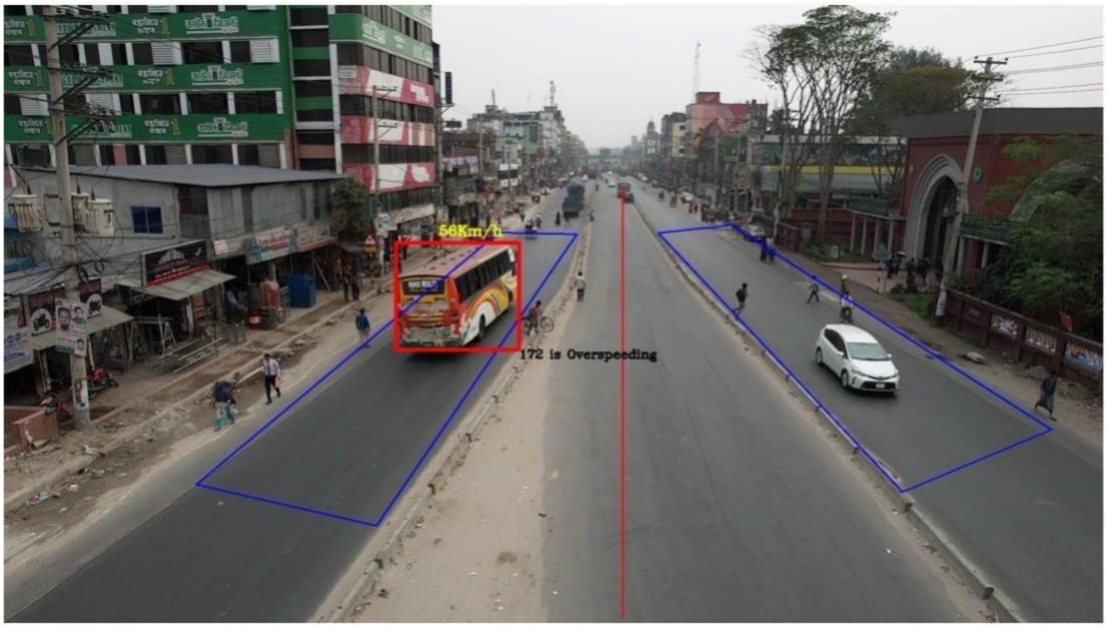

Figure 5.3: Performance of over-speeding detection

The system's ability to accurately detect speeding offences reveals its capacity to evaluate vehicle motion and velocity, which enables real-time monitoring and intervention for possible issues with traffic safety.

In order to evaluate the performance of the wrong way driving detection algorithm, a unique test scenario was devised where the right and wrong lanes were reversed. By intentionally modifying the video frames, all vehicles were made to appear as if they were driving in the wrong direction.

The system successfully detected and flagged all vehicles in this reversed situation

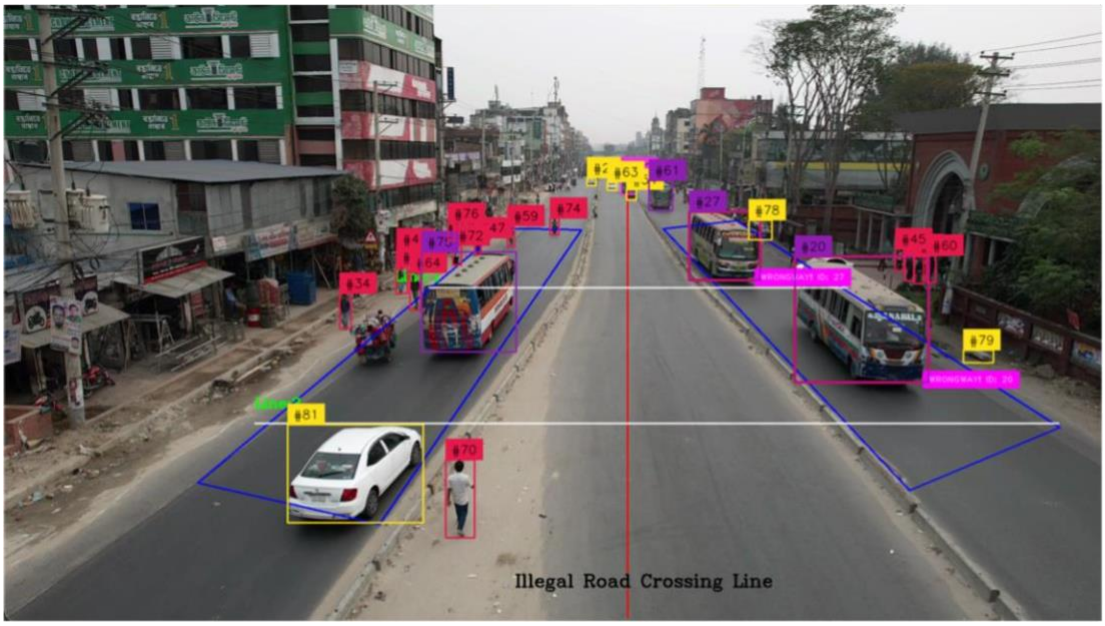

Figure 5.4: Performance of wrong way detection

as wrong way driving instances. It is important to note that in the original test clip, no actual instances of wrong way driving were observed. However, the system's ability to accurately identify vehicles moving in the opposite direction of the designated lane highlights its effectiveness in detecting wrong way driving when presented withappropriate test conditions.

When it came to the detection of traffic offences, the integrated system was able to reach an excellent accuracy rate of 95 percent. The system accurately identified and marked 19 of the 20 violations that were present in the test clip. This high success rate is indicative of the system's robustness and efficacy in effectively recognizing and classifying a wide variety of traffic violations. The capability of the system to incorporate numerous detection algorithms and give reliable findings demonstrates its potential for improving road safety, assisting law enforcement agencies, and contributing to the development of successful methods for traffic management.

5.3 Illegal Vehicle Detection Performance

Training Results

350 images of illegal vehicles were annotated to train our custom model using YOLOv8s.The training was continued for 50 epochs. The training result can be observed through the following graphs and confusion matrix.

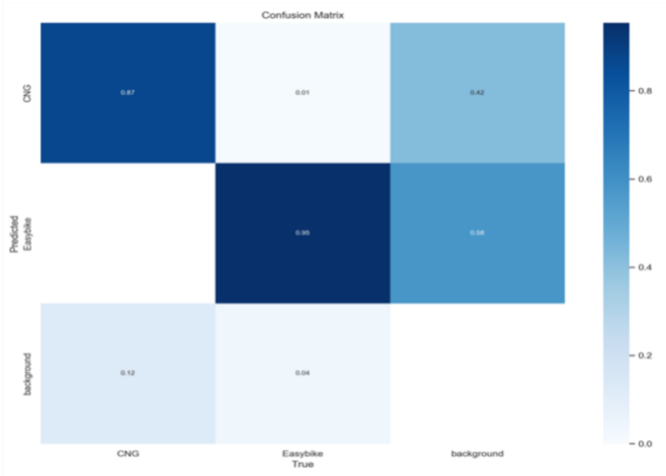

Figure 5.5: Confusion Matrix of trained model

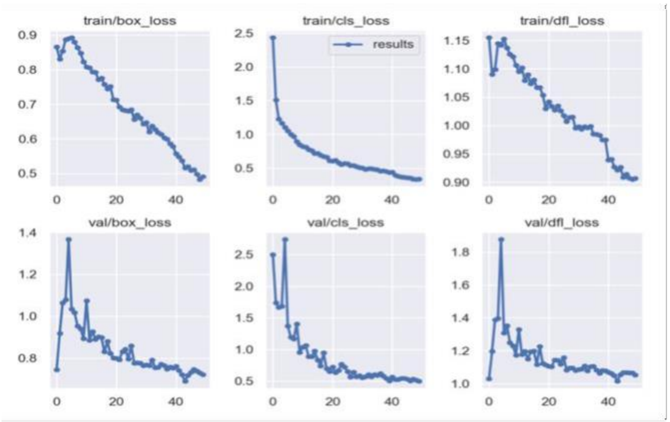

Figure 5.6: Various Loss functions of trained model

It can be observed from the confusion matrix that the overall performance of the custom trained model is satisfactory. The various loss functions are also declining in nature which also indicates accurate result.

The mean average precision is one of the key parameters to evaluate a model's performance. The mAP50 is the mean average precision at IOU set to 0.5 threshold. The

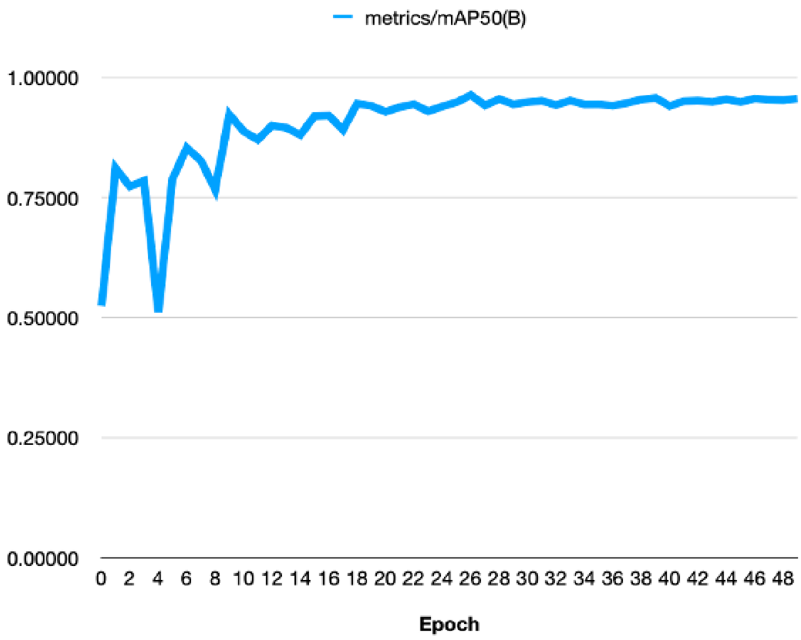

Figure 5.7: Mean Average Precision with respect to number of Epoch

higher the value of mAP50, the better will be the detection. In this case, it can be observed that the mAP50 is 95.6 percent after 50 epoch. Although this is a satisfactory result but mAP50 could be easily increased if a higher number of epoch is used. Another way to improve the model's performance is to use heavier YOLO models like YOLOv8m, YOLOv8l etc. These model's need higher computational power. As there were limitations in computational power, YOLOv8s model which is lighter but gives a fairly accurate result was used.

Performance Analysis

To test the performance of the proposed model, a video of Dhaka-Mymensingh highway in front of Islamic University of Technology was taken.

The video was 3 minutes long and the frame rate was 24 fps. 8 illegal vehicles went through the video and 7 were detected and flagged. So, the overall accuracy is 87.5 percent.

So, the model gives excellent result. Using this model, movement of illegal vehicles on Bangladeshi highways can be stopped effectively.

Figure 5.8: Input Frame of the system

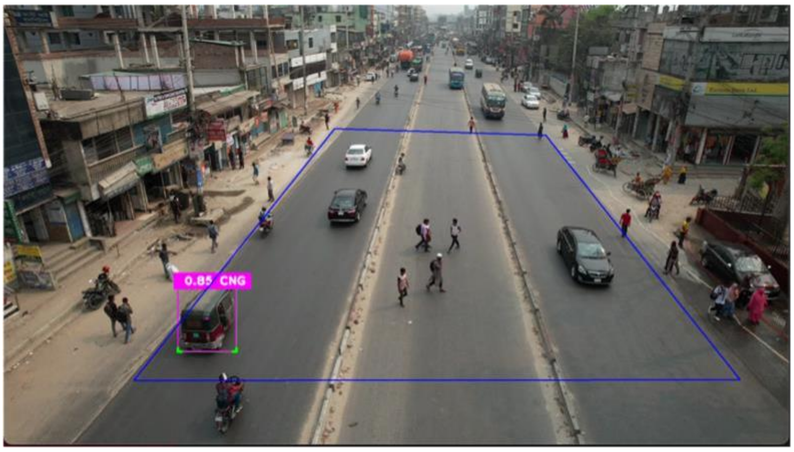

Figure 5.9: Output Frame of the system

5.4 Discussion of Results

The creation and adoption of cutting-edge technologies to monitor and enforce traffic laws has been pushed in recent years by the growing difficulties and concerns related to road safety. These technologies include computer vision-based systems, which have drawn a lot of interest because of their capacity to examine visual data obtained by cameras placed along highways and roads. The implementation of a computer vision-based integrated highway traffic violations detection system for Bangladesh is the main topic of our research. By identifying and correcting several rules breaches, such as wrong-way driving, pedestrian road crossings, banned vehicle presence, and overspeed driving incidents, the system seeks to increase road safety and to encourage safer driving habits, lower accident rates, and enhance overall traffic management on highway. For the different types of identification, a different sort of result was obtained.

5.4.1 Wrong Way Driving Detection

In the context of highway traffic violations detection, wrong way driving detection plays a crucial role in ensuring road safety. The proposed integrated system can effectively detect vehicles traveling in the wrong direction. The system can analyze the flow of traffic, identify vehicles moving against the expected direction, and store the violating vehicles' data in a separate database. The results of this detection is evaluated in terms of accuracy, showcasing the system's ability to detect and respond to wrong way driving instances accurately and in a timely manner.

5.4.2 Pedestrian Road Crossing

Pedestrian safety is a paramount concern in traffic management systems. By analyzing video or image inputs from cameras installed along the road, the proposed system can identify and classify pedestrians attempting to cross the road. The evaluation of results is focused on metrics such as detection accuracy, pedestrian tracking precision to assess the system's performance.

5.4.3 Illegal Vehicle Detection

Illegal vehicles, such as cng driven auto-rickshaws, easy-bike etc are a common mode of transportation in Bangladesh. However, their presence on highways or roads where they are not allowed can pose safety risks. The proposed system can detect and classify illegal vehicles, allowing authorities to take appropriate actions. The evaluation of results is focused on detection accuracy and the system's ability to identify those vehicles accurately and differentiate them from other vehicles on the road.

5.4.4 Over-speed Detection

Monitoring vehicle speeds is essential for enforcing traffic regulations and ensuring road safety. Computer vision techniques can be employed to estimate the speed of vehicles by analyzing their motion in video frames or images. By detecting and tracking vehicles, the proposed system can calculate their speeds and identify instances speeding. The system also stores the violating frame containing over-speed violation in a separate database so that traffic authorities can take legal actions.

In conclusion, the discussion of results for each of these points in the paper on ”Integrated Traffic Violations Detection System for the Highways of Bangladesh” will provide a complete violation identification system which will efficiently detect wrong-way driving, illegal pedestrian road crossing, three-wheelers which are banned in highways and over-speeding.

5.5 Fulfillment of the Objective and Expected Outcome

The proposed model is able to quickly identify the three different forms of traffic offenses that were discussed in this research. These three types of traffic violations—driving the wrong way on a one-way street, illegally crossing a road with people, and going too fast for conditions—can all be identified simultaneously by the system that has been developed. In the past, there has not been a study of this nature that brought together all three types of infractions into a single comprehensive framework. On the other hand, this technique makes it possible to quickly identify any one of the breaches. The first objective can now be considered accomplished in this manner.

In order to compile a unique dataset, a DJI Mavic Air2s drone was put to use in order to take pictures of unlawful vehicles such as CNG driven auto-rickshaws and Easybikes while flying over various roadways. After being annotated, these photographs were used to train a custom YOLO model, which is now being used to identify illegal vehicles on Bangladeshi highways. The customized model performed exceptionally well and was able to identify seven of the eight unlawful automobiles that were included in the test footage. As a result, the second objective has been attained.

The integrated traffic violations detection system was constructed with the help of YOLOv8, the most recent version of the YOLO software developed by Ultralytics. In terms of accuracy, YOLOv8 is superior to all of the prior versions. The accuracy rate of the system was able to be improved to 95 percent, which is a significant improvement. Nineteen out of twenty infractions that were discovered in the test footage were appropriately identified and marked by the system. This high success rate is evidence of the system’s power and efficacy in correctly identifying and classifying a wide variety of traffic offenses. The third objective can be considered accomplished in this manner.

Chapter 6

Conclusion and Future Works

The research paper "Integrated Traffic Violations Detection System for the Highways of Bangladesh" presents a comprehensive study on the development and implementation of an innovative integrated traffic violation monitoring system. Through the integration of computer vision technologies and integrated algorithms, this system aims to detect and document various traffic rule violations in real-time, providing an effective means to promote responsible driving behavior and subsequently reduce traffic congestion.

The research highlights the increasing challenges faced by traditional traffic surveillance due to multiple rule breakings and emphasizes the need for automated and intelligent systems. By harnessing the power of computer vision, the proposed system can effectively analyze real-time video footage to detect various traffic violations such as speeding, wrong way driving, illegal road crossing and illegal vehicle running. This technology enables law enforcement agencies to promptly identify and address violations, contributing to improved road traffic management.

To add to that, the study discusses the key components of the system, including vehicle detection, tracking algorithms and violation classification. The integration of a deep learning model like YOLOv8, plays a vital role in achieving accurate and robust results. The evaluation of the integrated system using drone footages were taken from the same height in which CC cameras are placed demonstrates its high detection rates validating its effectiveness in real-world scenarios.

Furthermore, the development of this integrated detection system recognizes the unique challenges and requirements of the Bangladeshi context. The excessive traffic size, diversified vehicle types, complicated road conditions and everchanging driving culture demand a customized solution that takes into account the specific characteristics of the local highways. By leveraging advanced image processing algorithms, pattern recognition techniques and machine learning models, the proposed system has the potential to automatically identify violations such as over-speeding, illegal road crossing, wrong way driving and violations by specific vehicles like CNG-driven auto-rickshaws and rickshaws.

Implementing a network of strategically placed cameras and sensors, the system captures relevant visual data and transmits it for analysis and enforcement. This real-time monitoring capability not only allows for prompt detection of violations but also provides valuable data for traffic management and decision-making. By facilitating efficient enforcement, the system can serve as a deterrent to reckless driving behavior and contribute to improved road safety.

However, it is important to recognize that the implementation of such a system requires careful consideration of technical feasibility, infrastructure requirements, legal and privacy implications, and stakeholder collaboration. Collaboration between government authorities, law enforcement agencies and relevant stakeholders will be crucial to the successful implementation and maintenance of the system.

While this study has provided a comprehensive overview of the proposed system and its potential benefits, further research and development are needed to refine and optimize the system's performance. Continuous improvements in computer vision technology, machine learning algorithms and data processing capabilities will enhance the accuracy, efficiency and scalability of the system. Overall, the research has the potential to significantly contribute to road safety and traffic management in Bangladesh. By leveraging technology and integrated monitoring, it offers a proactive approach to address traffic rule violations and promote responsible driving behavior, ultimatelyworking towards creating safer and more efficient highways for all road users.

6.1 Limitation

Though the expected outcomes of the research can prove to be handy, there were some shortcomings because of a few limitations in the procedure. The computational power of the model is very limited as a lighter version of YOLOv8n was used. YOLOv8m or YOLOv8l, more powerful versions would have proven to provide better results because of its higher computational prowess. On the other hand, if more epoch was used to train the illegal vehicle detection model then the accuracy of the system would have been far greater. But due to low computational ability available–YOLOv8n–a lower epoch was used which resulted in less accurate detections.

To add to that, the COCO dataset used for training the combined algorithm did not provide classified illegal vehicle data. For this reason, illegal vehicle detection could not be integrated into the whole combined model.

6.2 Future Work

Like every research there is also room for improvement and future work in this research. Firstly, all of the data containing violating vehicles' image, obtained from the model is stored in a separate database. In future, ANPR technology could be added to the model for which the number plate of a traffic rule violating vehicle can also be found which, in turn, will prove useful for the authority in identifying a criminal driver. Subsequently, a real time notification can be sent to the police authority which can bring beneficial change in the system. Lastly, other types of violation such as bikers without helmet, three passengers riding a motorcycle, red-light detection etc. can be added to the proposed integrated traffic violations detection system to make it more efficient and robust.

Appendix A

List of Appendices

A.1 Simulation Code for Detecting Over-speed

```python
if cy1 > (cy - offset) and cy1 < (cy + offset):
    vh_down[detections.tracker_id[loop_id]] = time.time()

if detections.tracker_id[loop_id] in vh_down:

    if cy2 > (cy - offset) and cy2 < (cy + offset):
        elapsed_time = time.time() - vh_down[detections.tracker_id[loop_id]]

        if counter.count(detections.tracker_id[loop_id]) == 0:
            counter.append(detections.tracker_id[loop_id])
            distance = 20.45  # meters
            a_speed_ms = distance / elapsed_time
            a_speed_kh = a_speed_ms * 3.6 * 9.63
            cv2.circle(frame, (cx, cy), 4, (0, 0, 255), 2)
            cv2.putText(frame, str(detections.tracker_id[loop_id]), (x1, y1),
                        cv2.FONT_HERSHEY_COMPLEX, 0.6, (255, 255, 255), 1)
            cv2.putText(frame, str(int(a_speed_kh)) + 'Km/h', (x1+74, y1-13), cv2.FONT_HERSHEY_COMPLEX, 0.8,
                (0, 255, 255), 2)
            if a_speed_kh > 50:
                cv2.rectangle(frame, (x1, y1), (x2, y2), (0, 0, 255), 5)
                cv2.putText(frame, str(int(detections.tracker_id[loop_id])) + ' is Overspeeding',
                            (x2, y2+15),
                            cv2.FONT_HERSHEY_COMPLEX, 0.7,
                            (0, 0, 0), 2)
                imgwrite(frame)
                print("Overspeeding ID: " + str(detections.tracker_id[loop_id]))
```

Figure A.1.1: Over-speeding algorithm applied for the right lane

```python
if cy2 < (cy + offset) and cy2 > (cy - offset):
    vh_up[detections.tracker_id[loop_id]] = time.time()

if detections.tracker_id[loop_id] in vh_up:

    if cy1 < (cy + offset) and cy1 > (cy - offset):
        elapsed1_time = time.time() - vh_up[detections.tracker_id[loop_id]]

        if counter1.count(detections.tracker_id[loop_id]) == 0:
            counter1.append(detections.tracker_id[loop_id])
            distance1 = 20.45  # meters
            a_speed_ms1 = distance1 / elapsed1_time
            a_speed_kh1 = a_speed_ms1 * 3.6 * 9.63
            cv2.circle(frame, (cx, cy), 4, (0, 0, 255), -1)
            cv2.putText(frame, str(detections.tracker_id[loop_id]), (x1, y1), cv2.FONT_HERSHEY_COMPLEX, 0.6,
                (255, 255, 255), 1)
            cv2.putText(frame, str(int(a_speed_kh1)) + 'Km/h', (x1+75, y1-13), cv2.FONT_HERSHEY_COMPLEX, 0.8,
                (0, 255, 255), 2)
            if a_speed_kh1 > 50:
                cv2.rectangle(frame, (x1, y1), (x2, y2), (0, 0, 255), 5)
                cv2.putText(frame, str(int(detections.tracker_id[loop_id])) + ' is Overspeeding',
                            (x2, y2+15),
                            cv2.FONT_HERSHEY_COMPLEX, 0.7,
                            (0, 0, 0), 2)
                imgwrite(frame)
                print("Overspeeding ID: " + str(detections.tracker_id[loop_id]))
```

Figure A.1.2: Over-speeding algorithm applied for the left lane

A.2 Simulation Code for Detecting Wrong-way Driving

```python
results1 = cv2.pointPolygonTest(np.array(area1, np.int32), ((cx, cy)), False)
results = cv2.pointPolygonTest(np.array(area2, np.int32), ((cx, cy)), False)
if results >= 0:
    if detections.tracker_id[loop_id] in id_yvals:
        if cy > id_yvals[detections.tracker_id[loop_id]]['cy']:
            print(f"Vehicle with ID {detections.tracker_id[loop_id]} is driving in the wrong direction!")
            cv2.rectangle(frame, (x1, y1), (x2, y2), (0, 0, 255), 3)
            cvzone.putTextRect(frame, f'WRONGWAY! ID: {int(detections.tracker_id[loop_id])}', (x2,y2), scale=1,
                               thickness=1,
                               offset=10)
            imgwrite(frame)
        if cy < id_yvals[detections.tracker_id[loop_id]]['cy']:
            print("Wrong Direction")
        # update y1 and y2 values in dictionary
    else:
        # add new ID to dictionary
        id_yvals[detections.tracker_id[loop_id]] = {'cx': cx, 'cy': cy}
if results1 >= 0 :
    if detections.tracker_id[loop_id] in id_yvals1:

        # check if y1 and y2 values are decreasing
        if cy > id_yvals1[detections.tracker_id[loop_id]]['cy']:
            print(f"Vehicle with ID {detections.tracker_id[loop_id]} is driving in the wrong direction!")
            cv2.rectangle(frame, (x1, y1), (x2, y2), (0, 0, 255), 3)
            cvzone.putTextRect(frame, f'WRONGWAY! ID: {int(detections.tracker_id[loop_id])}', (x2,y2), scale=1,thickness=1,
                               offset=10)
            imgwrite(frame)

        if cy < id_yvals1[detections.tracker_id[loop_id]]['cy']:
            print("Wrong Direction")
        # update y1 and y2 values in dictionary
    else:
        # add new ID to dictionary
        id_yvals1[detections.tracker_id[loop_id]] = {'cx': cx, 'cy': cy}
```

Figure A.2: Wrong-way Driving Detection

A.3 Simulation Code for FPS Calculation

```python
starting_time=time.time()
count=0
```

Figure A.3.1: Starting time and initialization of frame-count to calculate fps

```python
ending_time=time.time()
FPS=count/(starting_time-ending_time)
print(FPS)
```

Figure A.3.2: FPS Calculation and Display

A.4 Simulation Code for Drawing lines and texts on the frame

```
cv2.line(frame, (736, cy1), (1458, cy1), (255,255,255), 2)
cv2.putText(frame, ('Line:1'), (676, 488), cv2.FONT_HERSHEY_COMPLEX, 0.8, (0, 255, 0), 2)

cv2.line(frame, (434, cy2), (1827, cy2), (255, 255, 255), 2)

cv2.putText(frame, ('Line:2'), (434, 708), cv2.FONT_HERSHEY_COMPLEX, 0.8, (0, 255, 0), 2)
d = (len(counter))
u = (len(counter1))
cv2.putText(frame, ('Illegal Road Crossing Line'), (885, 1018), cv2.FONT_HERSHEY_COMPLEX, 1, (0, 0, 0), 2)
```

Figure A.4: Drawing lines and texts on the frame

A.5 Simulation Code for Detecting Illegal Vehicles

```
from ultralytics import YOLO
import cv2
import cvzone
import math
cap = cv2.VideoCapture("cng.mov")  # For Video

model=YOLO('bestcng.pt')

classNames = ["illegal_vehicles"]

while True:
    success, img = cap.read()
    results = model(img, stream=True)

    for r in results:
        boxes = r.boxes
        for box in boxes:
            # Bounding Box
            x1, y1, x2, y2 = box.xyxy[0]
            x1, y1, x2, y2 = int(x1), int(y1), int(x2), int(y2)
            w, h = x2 - x1, y2 - y1

            conf = math.ceil((box.conf[0] * 100)) / 100
            cls = int(box.cls[0])
            currentClass=classNames[cls]
            if conf>0.6:
                cvzone.putTextRect(img, f'{classNames[cls]} {conf}', (max(0, x1), max(35, y1)),scale=2 ,thickness=3,offset=3)
                cvzone.cornerRect(img, (x1, y1, w, h), l=15)

    cv2.imshow("Image", img)
    # cv2.imshow("ImageRegion", imgRegion)
    cv2.waitKey(1)
```

Figure A.5: Illegal Vehicle Detection

A.6 Simulation Code for Detecting Illegal Road Crossing

```
if name == 'person':
    cx = int(x1 + x2) // 2
    cy = int(y1 + y2) // 2
    if cx > (cx1 - offset) and cx < (cx1 + offset):
        cv2.putText(frame, str('Illegal Crossing!!'), (x2, y2), cv2.FONT_HERSHEY_COMPLEX, 0.7, (0, 0, 255), 2)
        imgwrite(frame)
    if cx < (cx1 - offset) and cx > (cx1 + offset):
        cv2.putText(frame, str('Illegal Crossing!!'), (x2, y2), cv2.FONT_HERSHEY_COMPLEX, 0.7, (0, 0, 255), 2)
        imgwrite(frame)
```

Figure A.6: Illegal Road Crossing Detection

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