Intelligent Traffic Violation Detection

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Intelligent Traffic Violation Detection

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***Abstract*— ITVD is a technique which uses Artificial Intelligence and deep learning concepts to detect the vehicle violating the traffic rules. We observe that in the past few years there has been a tremendous increase in the number of on road vehicles. The congested roads with pollution, thereby creating havoc which serves as a reason to violate the traffic rules. This in turn increases road accidents. ITVD is an algorithm which detects traffic violations such as jumping red signals, riding vehicles without helmets, driving without seat belts and vehicles stepping over the stop line during red signals. In many developing countries like India, traffic violations are monitored manually by the traffic department. Such systems make the law enforcement and traffic management difficult since it requires tracking of each vehicle without a miss. This necessitates an automated system which detects the traffic violations and abnormal events occurring on the roads.**

In this paper we propose the YOLOv3(You Only Look Once version3) algorithm to detect the traffic violations. This algorithm uses Convolutional Neural Networks (CNN) to detect an object and Darknet-53 as a feature extractor. The main advantage of using YOLOv3 is that it uses clustering analysis to cluster the input dataset to improve the prediction ability even with small vehicles.

Keywords*— *Intelligent Traffic Violation detection, Yolov3 algorithm, Darknet53 feature extractor, CNN model, Traffic management system.

I. Introduction

Road traffic violation rules differ from one country to another. In India traffic violations rules follow the Motor Vehicle Act 1988, passed by the Lok Sabha with strict and heavy penalties for violation of traffic rules [1]. The key features of the amendment include: 3 years imprisonment to the parents of drivers less than 18 years of age, increase in the compensation to the individual who met with an accident, increase in the fines for the violations such as rash driving, drunken driving, driving without helmet and seat belts. According to the fact, more than 1.5 lakh people die in road accidents, where 95% casualties involve two wheelers. Bengaluru, a city of Karnataka state in India, is considered as a third place in road accidents [2]. Karnataka state government decides on the roles of the officials for traffic rule enforcement. Generally state traffic police can book traffic violations against a person for breaking the traffic rules. Recently, there is an increase in the number of vehicles on roads and is rapidly increasing day by day, which thus causes profoundly clogged streets thereby encouraging the violators to break the rules. The main intention is to save time. These violators leave in a common conception that red signals, wearing helmets and other rules are a waste of time and fuel, wearing a helmet will make you look awful, blocks vision, impaired hearing, gives helmet hair and many more reasons. Manual checking of vehicles violating rules is tedious. This requires a system which detects and distinguishes a variety of traffic offenses. For example signal hop, over speeding, riding without a helmet. Also such a system should effectively monitor the traffic to enforce law and order in the city.

Traffic violation is a serious offence, which could endanger the lives of drivers and pedestrians. Because of the violations, real time problems including increased travel time, excess fuel consumption, fatigue, and increased pollution can be observed. In many countries it is very common for drivers to pay the fine, get issued traffic tickets, or even get arrested due to violations and charges.

The traffic violations are categorized into two types as minor and major violations [3]. Minor violations include, parking violations in an unauthorized space or no parking zone, handicapped zone or at trespassing areas. Major violations include more serious issues such as reckless driving and accident issues. Traffic laws differ across the state and city. It is the individual's responsibility to know the legal rights before entering the city. In most countries punishment for breaking the traffic rules is strict which leads to dismissal of license. List of documents to carry when riding a two-wheeler on Indian roads: Driver’s license, Vehicle registration certificate, Pollution check certificate which must be regenerated before the expiry of the previous certificate and vehicle insurance document.

In this paper, the proposed YOLOv3 algorithm is used to detect the traffic violation. The violations detected are vehicles jumping red signals, vehicle riding without helmets and vehicle drivers without seat belts. This technique identifies multiple objects in a single frame. The important factor of this algorithm is object detection which is identified by drawing boundaries around the object. In order to extract the feature, a Darknet-53, a multi-scale spatial pyramid pooling block is introduced in the darknet network to enable the network to learn the features more efficiently. It can be implemented by using python language. The remaining part of the paper is organized such that Section II discusses the Literature Survey, Section III explains the Implementation details, Section IV discusses the results and analysis, finally section V Concludes the paper with Future scope.

II. Literature Survey

Author R. J. Franklin et. al [4], proposes an algorithm called YOLOv3 to detect an object and neural network algorithm suitable for traffic violation detection for detecting multiple violations from single input. In this paper the author is trying to detect the speed of a moving vehicle. The algorithm offers “precision of 97.67% for vehicle identification and an exactness of 89.24% to identify the vehicle speed." The author uses Equation 1 to calculate the type of object.

Type of object = (5+ class prob)*3 (1)

where, "the number 5 indicates four signifies properties of bounding boxes i.e height (bh), width (bw), x and y indicate the condition of the given bouncing boxes (bx, by) inside a given output image. One is the probability of the identifying object. And class probabilities are the probabilities for each class c1, c2, …c80. The whole summation is multiplied by three, this causes each cell to predict 3 bounding boxes. This outcome yields 10647 bounding boxes for the input image." The algorithm detects the total number of vehicles with an accuracy of 97%. The conclusion is based on just two test cases. Instead, a few more test cases must be added to summon up the results.

In another paper by author Xiaoling Wang et. al, [5] proposes an enhanced background approach algorithm which uses wavelet transform on objects in motion. Here the road traffic violation is detected using C++ with OpenCV." The dynamic foundation update calculation uses a weighting element to control the speed of the background image.

The author uses the below mentioned Equation 2 formula to calculate speed of the background updation.

$$I_d(x,y) = \alpha I_s(x,y) + (1-\alpha) I_d(x,y) \quad (2)$$

Where, "$I_s(x,y)$ is the coordinate of the source image and $I_d(x,y)$ is the coordinate of the background image. α is a weighting factor that is used to adjust the speed of background update within the current image."

The author uses Equation 3 to find the specific region of detection in an image.

$$r = \frac{A_{rect}}{A_{roi}} \quad (3)$$

where "A_{rect} is the area of rectangle and A_{roi} is the area under the region of interest. When r > ½, the rectangle captures the tracked object.

The author uses Equation 4 and 5 to calculate the center of gravity of a moving object.

$$M_{00} = \sum_1^{n_k} w_i, M_{10} = \sum_1^{n_k} w_i\, x \quad (4)$$

$$M_{01} = \sum_1^{n_k} w_i\, y, M(x,y) = \left(\frac{M_{10}}{M_{00}}, \frac{M_{01}}{M_{00}}\right) \quad (5)$$

Where, "M_{00} is the zeroth-order moment of w_i, M_{10} and M_{01} are the first order moments of w_i, and M(x,y) is the center of gravity. Continuous change in the tracking center to M(x,y) ,until the distance between the center and M(x,y) is not less than threshold value T. The new window can be acquired as the search box of the following frame." α significantly affects the precision of vehicle detection. If the background gets updated too fast, then an extra-holes gets generated in the foreground image, otherwise no holes.

The author uses OpenCV library functions, example GaussianBlur() used as Gaussian filter, cvtColor() used as image space mapping, absdiff() used for background subtraction, threshold() to calculate threshold, canny() to detect Canny edge, calcHist() to calculate histogram, etc.

In another paper by author HR Mampilayil et. al, [6] proposes automated surveillance to detect three-wheeler vehicles and a technique to recognize one-way traffic rule violation detection. Proposed a framework that can distinguish vehicles which are moving against the one way trajectory of a moving traffic. "For each frame of input video, the optical movement stream and for each block median of flow is determined. When the difference between the direction flow of the current image and the corresponding cell-block is larger than 2.57 then the object is defined as moving in the wrong direction."

To validate this theory the author has utilized two techniques i.e. temporal violation and appearance-based violation. The same is used to validate the object as a car using its coherent trajectory. This paper discusses one of the discoveries where the author built up a technique to consequently recognize number plates of the vehicle. The paper likewise represents another administrative work which centers around tallying the quantity of vehicles on the road. Edge distinction, morphology, versatile edge, edge identification are the techniques used to differentiate vehicles. The drawback was, the algorithm was detecting both cars and trucks as cars. The proposed framework takes the video information, transfers from the camera which is fixed on the side of the road. The directional motion of a vehicle is calculated by the "difference between the centroid coordinates of the input frame and the end buffer frame coordinates. For instance, if the value of x and y are positive and negative respectively then the object is moving in a south-east direction. After deciding the direction of each identified vehicle, if the course of that specific vehicle is against the direction of the road traffic which was initially set at the start, at that point the vehicle is violating a one way traffic rule." The author implemented this theory without any use of sensors.

In another paper by author S. A. Elsagheer Mohamed et. al, [7] proposes a theory to naturally recognize and record criminal offenses without the interference of the person by using a support vector machine to detect traffic violations. The author pointed out a drawback in Saudi Arabia's Saher system which detects traffic violations, i.e. the system couldn't detect violations where the length of roads was very long, most of the violators escaped without being caught. Secondly, identification of plate-numbers could not be guaranteed. Thirdly, there were not many cameras due to the expensive systems that are associated with centralized connected servers. One of the interesting facts with regards to this paper is that the author guarantees that the street mishaps have not decreased yet and has been the explanation behind the increase in the rate of accidents in Saudi. The author further explains that when the drivers hitting the roads at high speed unexpectedly notices a camera, they brake suddenly which leads to accidents. According to the Arab News dated 2nd November 2020, [8] the authors' claim is correct being that "Saher fails to reduce road deaths". But according to the news, "researchers at King Abdullah International Medical Research Center claim that failure of the system was because it had not been applied widely enough across the country". Author's statements were purely based on assumptions and not based on the facts. The author recommends that DGPS(Differential Global Positioning

System) compares with GPS, RSS and Nano-Tube innovation, which utilizes an organization of fixed ground stations. Each ground station knows the right supreme position. Accordingly, it can compute the difference between the acquired position and the absolute one. “It calculates the difference between the positions demonstrated by the satellite images and the position of the covering region. This enables all the GPS devices in that area to know the errors and subsequently correct the position.” The author proposes this theory by using Wireless Transceivers (WT), VANET protocols and other Ad-hoc devices to capture the activities on the road. The author uses various sensors to detect violations like speed limit, maintaining minimum distance between the vehicle to avoid accidents and vehicles moving in the wrong direction.

III. Implementation

This section discusses the implementation details of the ITVD.

A. *Video processing*

OpenCV is an open source library for python which is used for processing videos. OpenCV provides a way to perform any operation on video, frame by frame. A combination of multiple frames played in continuous manner seems like a video. OpenCV library provides few functionalities to perform operations on a video like smoothing, edge detection, bitwise operations, etc. This feature helps in enhancement or detection.

B. *System Architecture for Traffic Management:*

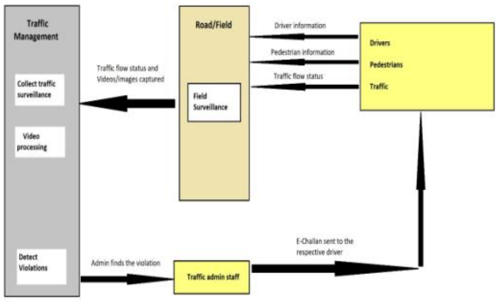

Fig. 1. Sub-System Architecture

Fig1. shows the proposed sub-system architecture, where the important component of the ITVD is the video processing part. The videos collected from the traffic police or the surveillance cameras can be acquired through the legacy network which is already in use. In this case, the data is being created manually i.e. captured from the high definition mobile cameras from different junctions with 60fps. These videos are processed and then, these inputs go through the YOLOV3 algorithm for object detection. Based on the training and test data, the violation gets detected.

Fig2. shows the basic workflow of the system and its subcomponents are highlighted below.

Field Surveillance – For the proposed work, the data can be either collected from the traffic surveillance cameras or can be created by capturing it from different locations manually.

Traffic admin staff – After the violation is detected, the admin will get the output image of the vehicle which violated the traffic and using the same old legacy E-Challan system, admin will generate a challan on the vehicle and send it to the respective vehicle owners.

Edge Devices - Edge devices are those which are used for the processing of the data collected from surveillance cameras or the data-set acquired from other data sources. Mainly two components are included which are monitoring devices to control the surveillance cameras placed at different junctions and the ITVD (Intelligent Traffic Violation Detection) system which is installed in the dedicated systems which acquire the surveillance data and process it to give the desired output.

Communication – The on field staff captures any kind of violations on the roads and then sends the captured data to the headquarters for further scrutiny. This project doesn’t aim at establishing a new network rather improvise the existing system in a better possible way.

Storage – The surveillance dataset or the acquired dataset can be stored directly in the allocated hard-drives allotted by the headquarters. There must be periodic proper maintenance of the system, in order to fully utilize the system resources.

Application – Will be using the legacy E-Challan application for sending the challans to the owners of vehicles violating the traffic rules. This project aims at automatizing the violation task using artificial intelligence and deep learning algorithms instead of creating a new dashboard for the traffic police. There are already appealing applications which are in use. The purpose of this project is to automatize and detect the traffic violations, which will remove human negligence, chance of getting escaped (0%), safety to deploy traffic police from furious drivers by getting abused, etc.

Devices/Users – There are surveillance cameras attached at every junction to collect the dataset and activity on the roads along with in the daytime traffic police deployed at the junctions also captures the videos and pictures of vehicles violating the traffic rules and then sending those data to the headquarters to generate challans against those vehicle owners.

C. *You Only Look Once version3(YOLOv3)*

YOLOv3 makes use of convolution layers. YOLOv3 uses an element extractor called DarkNet-53. It contains 53 convolutional layers, trailed by a bunch of normalization layers and broken ReLU layers. YOLO is one of the fastest ways to identify the object. In contrast with the other recognition algorithms, a YOLO doesn't just anticipate class marks but additionally distinguishes different areas of items too. YOLO applies a solitary Neural network to the Full Image. Which implies that this network separates the picture into distinct cells and predicts bounding boxes and probabilities for every region. These bounding boxes are weighted by the anticipated probabilities. The significant disadvantage in this calculation is that we need to handle our picture in groups, we need to have all pictures of fixed height and width. We need to perform these tasks to combine all the previous images in a single group.

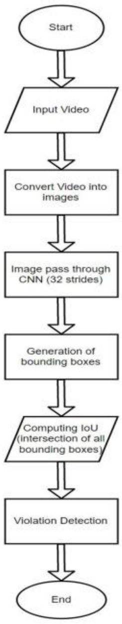

Fig. 2. Basic workflow diagram

Fig3. shows the CNN Darknet layer which down samples the picture by a factor called stride. In the event that a stride of 32 is utilized for a contribution of 416 X 416 size picture, that will yield a yield of size 13 X 13. We can likewise say that the stride is the factor by which the yield of the layer is greater than the input picture of the algorithm.

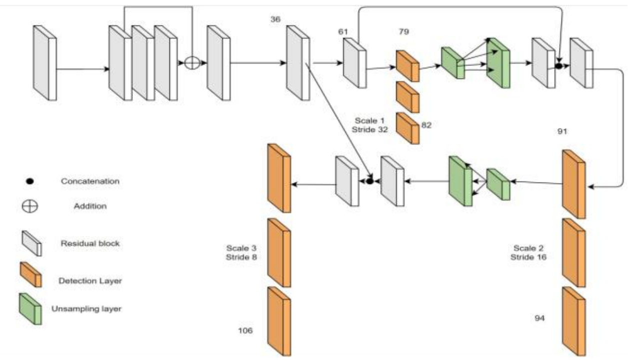

Fig. 3. CNN Darknet layer

	Type	Filters	Size	Output
	Convolutional	32	3 X 3	256 X 256
	Convolutional	64	3 X 3/2	128 X 128
1 X	Convolutional	32	1 X 1	
	Convolutional	64	3 X 3	
	Residual			128 X 128
	Convolutional	128	3 X 3/2	64 X 64
2 X	Convolutional	64	1 X 1	
	Convolutional	128	3 X 3	
	Residual			64 X 64
	Convolutional	256	3 X 3/2	32 X 32
8 X	Convolutional	128	1 X 1	
	Convolutional	256	3 X 3	
	Residual			32 X 32
	Convolutional	512	3 X 3/2	16 X 16
8 X	Convolutional	256	1 X 1	
	Convolutional	512	3 X 3	
	Residual			16 X 16
	Convolutional	1024	3 X 3/2	8 X 8
4 X	Convolutional	512	1 X 1	
	Convolutional	1024	3 X 3	
	Residual			8 X 8
	Avgpool		Global	
	Connected		1000	
	Softmax			

Fig. 4. Darknet-53 model

Fig4. shows the Darknet-53 model which is a type of CNN model which uses 53 layers. We can use a pre-trained version of the network which is trained on millions of images from the ImageNet database. The previously trained images classify thousands of categories resulting in the network to learn a huge number of image categories.

D. Violation Detection

The violation is detected by drawing the bounding boxes over the area which identifies the person wearing a helmet or not. The probability gets calculated for categorizing helmet detection. If the value is above 0.45 which means that the person is wearing a helmet. For seat belt detection features, we use the OpenCV functionality for edge detection by running smoothing functions and blurring the image. And then the lines are detected which have slope greater than 0.7 but less than 2, then detect the seat belt. For red signal jump detection, the user is asked to draw a line in front of the vehicles standing in a signal or over the zebra crossing and then detect the color of the signal. If the color of the signal is red and the vehicle crosses the line, then detect it as a violation. This way the proposed work emphasis on three features including Helmet detection, Seat belt detection and Red signal jump violations.

E. Bounding box calculation

Let’s consider a formula to calculate bounding box:

$$b_x = \sigma(t_x) + c_x$$

$$b_y = \sigma(t_y) + c_y b_y = \sigma(t_y) + c_y$$

$$b_w = p_w e^{t_w} b_w = p_w e^{t_w}$$

$$b_h = p_h e^{t_h}$$

Where b_x,b_x, b_y,b_y, b_w, $b_h b_w$, b_h are the center coordinate, predicted width and height t_x,t_x, t_y,t_y, t_w, t_h t_w, t_h is the network outcome. c_x and c_y c_x and c_y are the top-left points and p_w & $p_h p_w$ & p_h are anchor aspects for the box. Since the center coordinate values are predicted using sigmoid function, the value of output ranges from 0 to 1. In order to predict a perfect bounding box for an object we will be using IOU (Intersection Over Union).

i. Definition of boxes with its corner points (x1, y1, x2, y2).
ii. Calculate area of rectangle using the formula (y2-y1)*(x2-x1).
iii. Find the coordinate of intersection of boxes.
   a. xi = x1is the maximum of the two boxes i.e. xi1 = max(box1[0], box2[0])
   b. xi2 = x2 is the minimum of the two boxes i.e. xi2 = min(box1[2], box2[2])
   c. yi1 = y1 is the maximum of the two boxes i.e. yi1 = max(box1[1], box2[1])
   d. yi2 = y2 is the minimum of the two boxes i.e. yi2 = min(box1[3], box2[3])

intersection_area = (xi2-xi1)*(yi2-yi1)
formulae: Union(A,B) = A + B -Inter(A,B)
box1_area_1 = (box1[3]-box1[1])*(box1[2]-box1[0])
box2_area_2 = (box2[3]-box2[1])*(box2[2]-box2[0])

union_area_formulae = (box1_area_1 + box2_area_2) – intersection_area

Computing IoU

IoU = intersection_area / union_area_formulae

Algorithm –

1. Consider an input image (416,416,3).
2. The input image passes through CNN with stride as 32 resulting in (13,13,5,85)
3. In the wake of straightening the last two measurements, the yield is a volume of shape (13, 13,425):
   3.1. Every cell in a 13x13 matrix over the info picture gives 425 numbers.
   3.2. 425 = 5X85 since every cell contains expectations for 5 boxes, comparing to 5 anchor boxes.
   3.3. 85 = 5+80 where 5 is because (pc, bx, by, bh , bw) has numbers, and 80 is the number of classes which needs to be detected.
4. We then select few boxes based on:
   4.1. Score thresholding done by discarding boxes that distinguished a class with score not as much as edge.
   4.2. Non-max concealment: Compute the Intersection over Union and eliminate all the covering boxes.
5. This gives YOLO's last yield.

IV. Results and Analysis

Among the road traffic violations, the implementations included here are identifying motorists without helmets, Car drivers without seat belts and Red signal jump detection. The implementation is done using the YOLOv3 algorithm, darknet-53 (CNN) model and a few python libraries like OpenCV etc.

A. *Detection of motorist Without-Helmet*

As per the new rule enforced by Karnataka transport department, riding a 2-wheeler without helmet could result in suspension of driving license for 3 months. Along with the suspension, a fine will also be charged under Motor Vehicles Act for those violating the rules. According to section 129 of Motor Vehicles Act, 2-wheeler users above four years of age must wear a helmet. Fig 5 & 6 shows the implementation of helmet detection.

Fig. 5. Helmet Violation result outcome1

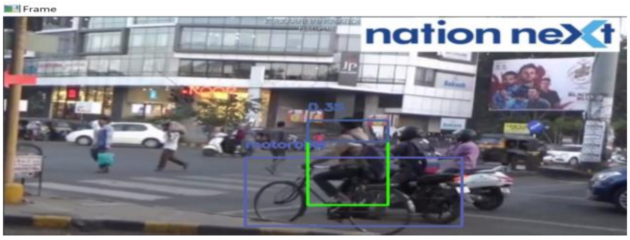

Fig. 6. Helmet Violation result outcome2

B. *Seat belt detection*

Fig 7,8 & 9 shows the implementation of seat belt detection.

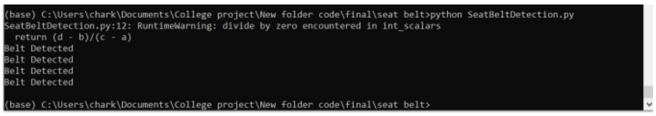

Fig. 7. Seat belt Violation result outcome1

Image before detection:

Fig. 8. Seat belt Violation result outcome2

Image after detection:

Fig. 9. Seat belt Violation result outcome3

C. *Red Signal jump detection*

Fig 10, 11, 12 & 13 shows the implementation of red signal jump violation.

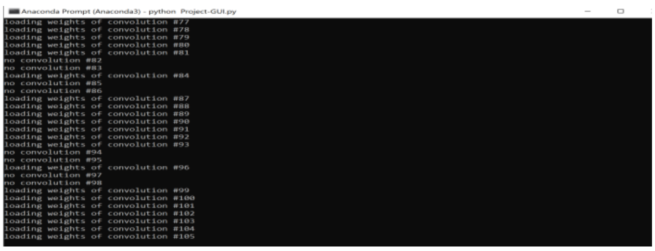

Fig. 10. Red signal jump Violation result outcome1

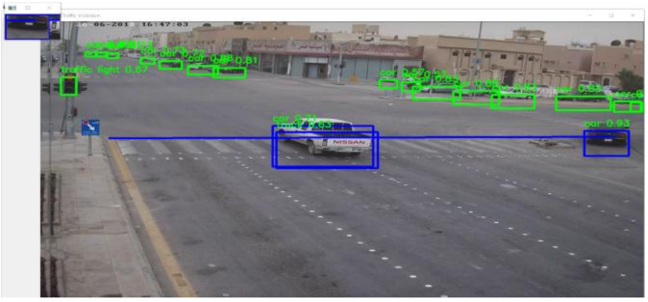

Fig. 11. Red signal jump Violation result outcome2

Fig. 12. Red signal jump Violation result outcome3

Fig. 13. Red signal jump Violation result outcome4

Let's discuss on the comparison table based on the accuracy of each feature discussed in this as well as other papers.

TABLE I. COMPARISON BETWEEN NETWORK MODEL USED IN PAPER[22] VERSES ITVD FOR HELMET DETECTION

Paper Reference	Network Model	Accuracy	Model size (Kb)
[22]	MobileNets	85.19%	16,754
ITVD	MobileNets	99.28%	12,053

In the above TABLE I the author N. Boonsirisumpun [22] has used VGG16, VGG19, Inception V3 and MobileNets model and has comes up with a conclusion as MobileNets model being the best model. The ITVD model enhances the accuracy of the model and improves its accuracy from 85.19% to 99.28% and also reduced the model size.

TABLE II. : COMPARISON BETWEEN PAPER[23] ACCURACY VERSES ITVD FOR SEAT BELT DETECTION

Paper Reference	Accuracy
[23]	93.20%
ITVD	92.80%

In the above TABLE II the author A. Kashevnik [23] shows the accuracy of 93.20% using YOLOv3 algorithm and IVDT given the accuracy of 92.80%.

TABLE III. COMPARISON BETWEEN PAPER[24] ACCURACY VERSES ITVD FOR RED SIGNAL JUMP VIOLATION DETECTION

Paper Reference	Accuracy
[24]	91.10%
ITVD	99.18%

In the above TABLE III the author S. S. Wankhede [24] shows an accuracy of 91.10% for vehicles over speeding but failed to provide an accuracy result for red signal jump. The proposed ITVD model gives an accuracy of 99.18% with a constraint which include the video dataset only when the signal is red. Green signal datasets are not considered for red signal jump violation.

V. CONCLUSION & FUTURE WORK

ITVD involves detection of vehicles violating traffic rules.

This paper proposes three automatic traffic violation detection using artificial intelligence and deep learning concepts. This paper uses the YOLOv3 concept for detecting 2-wheeler vehicles without helmet, seat belt detection and red signal jump violation features. The system will be very useful for Traffic Law enforcement authorities. The main benefits include reduced stress level, efficient and fast processing, 24/7 real time violation detection and reduced manual errors while monitoring.

Traffic violations can be detected in a day light. But for the night time it becomes a great challenging task for detecting any kind of violations. Not only night time but there are other factors which will affect the detection such as, weather conditions during day and night, camera quality used for surveillance, etc. The other real time issue faced by Karnataka Traffic Police is that they are finding it difficult to identify the vehicle violating the rules in night time because of high beam headlights used by vehicles during night. When light rays from these bright sources reach the front element of the camera lens, which reflects or bounces back different elements, thereby potentially diminishing the quality of an image or video. There is some more future work in this paper as the algorithm used to detect the violation is not optimized. It's a time-consuming process and needs few optimizations in the code.

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