COMPUTER VISION BASED APPROACH FOR OVERSPEEDING PROBLEM IN SMART TRAFFIC SYSTEM

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***Abstract*— With the growth in the urban population, count of vehicles on the road is also increasing drastically, traffic control in cities has become one of the most pressing challenges for the transportation system. A variety of different systems have been implemented across the country and around the world to resolve this issue. But most of them have proved inefficient to be implemented on a large scale that too in a developing country like India. Traffic management and related creative technologies are needed in the era of Machine Learning, Internet of Things (IoT), Image and Video processing, and Computer Vision in order to create more viable future cities. This paper presents a computer vision based approach for overspeed vehicle detection in Smart Traffic System (STS). Proposed overspeed vehicle detection system is based on centroid tracking and mark gap distance concept followed by OpenCV and Tesseract based method for license plate recognition. Primary purpose of the proposed system is to decrease cases of overspeeding and high death rates because of accidents. The accuracy of the proposed system is approximately 80% in detection of the overspeed vehicles.**

Keywords*— *Computer Vision, Smart Traffic System (STS) Overspeeding, OpenCV, Tesseract

I. INTRODUCTION

In recent years, cities are suffering significantly with the problem of traffic congestion. A tremendous amount of time is put in to provide mechanisms for traffic congestion detection and control. Thus, cities in different parts of the world are at different stages of traffic development, traffic control has become one of the main challenges for city transportation management. According to a report of the 'Ministry of Road Transport and Highways, Government of India', a total of 4,49,002 road accidents have been reported in India in the year 2019, which caused 1,51,113 lives and 4,51,361 injuries. Between 63% to 73% accidents and between 62% to 70% deaths are due to overspeeding of vehicles [1]. This involves excessive speeding, driving while impaired by alcohol or narcotics, and hit-and-run incidents. Overspeeding on two-wheelers and four-wheelers is a significant cause of accidents as shown in Fig. 1. According to [1], the number of road accident increased by approximately 14% and number of deaths due to road accidents have doubled in last two decade.

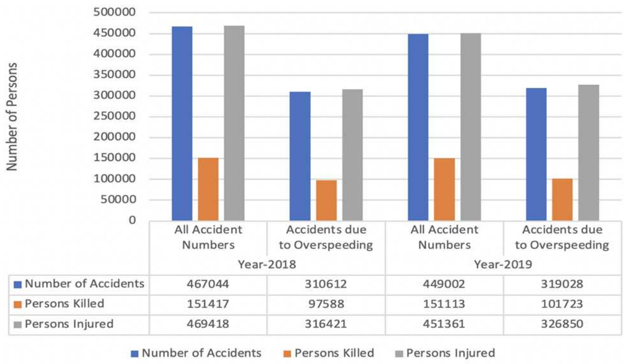

Fig. 1. Comparison of overall accident cases with accidents due to overspeeding [1]

If the number of on-road vehicles continues to rise at the current pace, it would be almost difficult to have enough manual labour to manage traffic in all congested areas. To help with traffic management in India and around the world, we need to develop accurate, efficient and cost-effective traffic monitoring systems. Complete hardware-based systems have been a failure when it comes to multi-lane speed detection and cost effectiveness. The hardware-based solutions do not work efficiently when there are a lot of vehicles in close range or if there is a lot of noise in the surroundings, which is exactly the case in the current scenario. Image and video analysis, computer vision have been recently tested and used in the area of traffic control systems in several countries. This paper presents a straightforward but accurate system for the detection of overspeed vehicles in multi-lane roads using centroid tracking and mark-gap distance. Overspeeding details (image of vehicle, speed, date and time) of overspeeding vehicles are sent to the firebase server and also used by the license plate recognition program running in parallel. OpenCV and tesseract are used for the extraction of license number from the image of the vehicle. After the extraction of license plate information, the system fetches vehicle owner details, overspeeding details from the database then sends a message to the nearest traffic police station, vehicle owner and also reflects all the overspeeding details on the web page. Efficiency of the method has been verified on pre-recorded videos/live video feeds of roads with a lot of vehicles in close range. So, this paper presents a computer vision based approach for overspeed vehicle detection and license plate recognition which is accurate, cost effective, and easier to implement than the current solutions and other expensive existing solutions. Proposed system is highly configurable and efficient to provide better quality of service to solve this problem.

II. Literature Review

In recent years, vehicle speed detection and license plate recognition have a pivotal role in the developing smart traffic management system. It is helpful to decrease the cases of overspeeding, accidents and it will also help in tracking vehicles for law enforcement, recognizing stolen vehicles, and traffic surveillance and control. In the literature review, research papers on vehicle speed detection and license plate recognition from 2000 to 2020 have been reviewed.

In [2] researchers described a method of vehicle speed detection using the Doppler effect. A radar device makes use of radio waves to calculate the speed of a vehicle. The radar device functions according to the principles of Doppler Effect. Doppler Effect describes the frequency shift associated with radio waves bouncing back from an object in motion. A well-known example of a Doppler shift is the change in pitch the sound of a vehicle, increases as the vehicle comes towards us and reduces as it moves away. It transmits low power microwave signals and receives energy coming back from objects. A micro controller is connected to the Doppler radar to receive frequency data from it which is used to calculate the speed of the vehicle. Despite this method’s low computation requirements, it was not preferred as it produces high inaccuracies for multilane roads and under varying weather conditions. In [3] researchers developed a new image-processing-based system for automatically monitoring vehicle speed from a video feed. It begins by describing a clear and simple method for detecting vehicles in digital image frames of a video stream, which is based on geometrical optics. According to preliminary data, all that is needed is a single digital video camera and an onboard computing system to measure vehicle speeds in multi-lane roads simultaneously. Vehicle speeds have an overall relative error of 4%. In [4] researchers described a method of vehicle speed detection using corner detection. In single lane, a system with Doppler sensor is capable of providing reliable results as there will be no other moving objects in its field of view. In this method researchers have given a low cost comprehensive yet versatile computer vision based approach for overspeeding vehicle detection. By making use of masking techniques and frame subtraction, vehicles which are moving are segmented. The distance traversed by the segmented object in each frame is used to approximate vehicle speed with low precision. Finally, frame masking is used to detect each vehicle individually. Our approach explored the idea of detecting vehicles using the approach mentioned in this paper, but it was not implemented as this method produces inaccuracies when vehicles are in close proximity. In [5] researchers proposed a system, which identifies vehicles which cross the specified speed limit and provides details to the concerned departments. The system has an IoT module, RFID and GSM module. If this proposed method is used in real time, then several accidents may be avoided. In [6] researchers presented an image processing based method of vehicle speed detection. Proposed method used a video feed for speed detection. Kalman filter, Gaussian mixture models, Optical flow, DBSCAN methods are used in the proposed method. Optical low method with the combination of Kalman filter tracking improves the accuracy of vehicle speed detection. Gaussian mixture model with DBSCAN is used for foreground detection. Experimental results represent that the system is able to provide good results even in the case of low quality cameras. In [7] researchers presented a target tracking algorithm to achieve high accuracy in speed detection. For background subtraction researchers used KNN algorithm. Proposed system shows high accuracy in real time conditions with an absolute 5% error. This paper follows a bit similar centroid tracking method to track the vehicles across different frames. In [8] researchers presented a system using infrared sensors and Raspberry Pi 3B+, to calculate the maximum speed of vehicles. System stores the images of vehicles in the database when the vehicle overspeeds the specified limits. This database can be used by concerned departments.

In [9] researchers described an automatic license plate detection method with support vector machines. The process of identifying license plates from vehicle photographs and marking them with their identification number is known as license recognition. It uses optical character recognition (OCR) on photographs to recognize symbols on license plates. The method for recognizing plate numbers usually involves plate localization, segmentation of the plate, extracting and marking the characters. The method then uses Support Vector Machine (SVM)-based learning and estimation on each character's measured Histograms of Oriented Gradients (HOG) characteristics. In [10] researchers presented a deep learning based automatic system for license plate recognition in which plate identification, character segmentation, and character recognition are the three components. Until applying the first Convolution Neural Network (CNN) model to identify the plates, multiple steps must be taken to detect the LP. Then it uses a second CNN model of 37 classes to segment the characters and identify them as uppercase letters and digits after a few preprocessing steps. The method is put to the test on two separate datasets that include photographs of vehicles in a variety of environments, including those with low picture quality, blurred images, sunny days, low illumination, and a dynamic world. The machine obtained findings that were reasonably reliable. Although it follows an extensive method to build an OCR model, a large dataset leads to few inaccurate results. In [11] researchers described a license plate recognition method based on OpenCV and tesseract. This method describes how to convert an image to text. This method finds all the text present in an image file and then puts all that data as actual text in another file. The python OpenCV library is used for processing images and image manipulation and tesseract is used for text recognition from that image. The variable level of image processing makes sure that different images are treated differently so as to produce optimized and reliable results. Our system follows a similar but more thorough approach for the license plate recognition involving various filters, detection of edges, contours, convex hulls followed by a perspective transform. In [12] researchers introduced an efficient license number recognition system which first detects vehicles and then identifies license plates from them to reduce FP on plate detection. Later CNN is applied for detecting characters in blurred and ambiguous images. The results obtained from experimenting on this system prove its superiority in terms of accuracy obtained and performance while comparing with usual LPR systems. In [13] researchers described an end-to-end license plate rectification and recognition method, without any complicated pre-processing, for irregular cases of license plate recognition such as tilt license plate images, complex background etc. Researchers used the Chinese Academy of Sciences CCPD dataset for testing, a variety of license plate images are present in this dataset. Proposed method achieves high accuracy on testing in the CCPD dataset.

III. Proposed Method

This paper presents a solution for overspeeding problem in STS. Complete workflow of the system has been shown in Fig. 2. First of all, system detects the overspeed vehicle in the live video feed/pre-recorded video feed of the road using the centroid tracking and mark-gap distance concept. If any vehicle breaks the maximum speed limit or overspeeds then overspeeding details (image of vehicle, speed, date and time) of that vehicle are stored to the firebase server, which act as cloud storage platform to store data for the system. Vehicle image from this stored data, is used by the license plate recognition program running in parallel. OpenCV and tesseract are used for the extraction of license number from the image of the vehicle and the extracted license number is stored in firebase server for that vehicle image. After the extraction of license plate information, the system fetches vehicle owner details, overspeeding details from the database for that license number. After that, the system sends a message to the nearest traffic police station and vehicle owner and also reflects overspeeding details on the web page. Proposed system uses the concept of multithreading, it means that all the components of the system as overspeed vehicle detection, data uploading/retrieval, license plate recognition and messaging service run in parallel using multithreading. Comprehensive description of each step, used tools and technology stack in every step, followed by our system is given as:

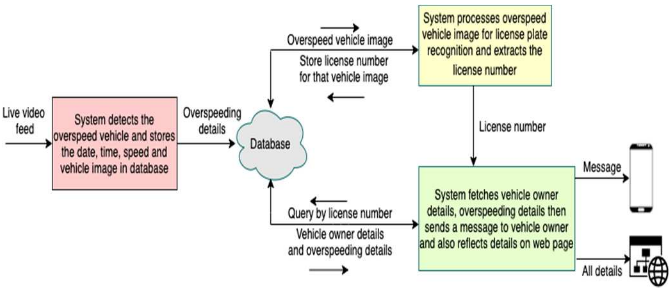

Fig. 2. Block diagram of the smart traffic system (STS)

The method was simulated on a system with the following configuration: Windows 10 Operating System, 8GB DDR4 RAM, Intel i5-8th Generation 1.6GHz Processor. For testing purposes, live video stream/pre-recorded video stream has been used as input to the program. Efficiency and accuracy of the system, maximum speed vehicle that our system can detect and track, depends on the processing power of the hardware used for simulation and also on the quality of provided video feed. Python programming language is used in this proposed method for scripting. Python is an interpreted, high level programming language with simple and easy to learn syntax. Python also provides support for object-oriented programming, multithreading, which encourages us to use it for development of our system.

Haar cascade classifier is used for vehicle detection in video streams. Haar cascade classifier is a machine learning model for object detection. It is used for object identification in an image or video stream. Haar cascade classifier based on the concept of features proposed by Paul Viola and Michael Jones in their paper [14]. Haar cascade classifier is trained with a lot of positive and negative images and after training it is used for object identification in other images or video streams. It can be trained for the identification of almost any object. So, Haar cascade classifier is used for vehicle detection in video streams [15].

In this part, a straightforward but accurate method is applied to estimate the speed of vehicles on multi-lane roads (Fig. 3). First of all, the regions which are not our region of interest (Region B) are cleared and clearing those also saves the processing time of the system. The regions which are far away (Region C) are also cleared. System processes the video feed frame by frame and system converts the frame image to single channel grayscale and thus it speeds up the processing speed. After that, centroid tracking is used to track each vehicle in every frame of video feed and assign the vehicle ID. Let (x, y) are the top-left coordinates of the new vehicle in the current frame, while w, h are the width and height of the bounding box for that new vehicle and the centroid of the new vehicle is calculated that is (x', y'). To assign the vehicle ID of a new vehicle, program loop over all the vehicle IDs from the previous frame and find their centroids. Here is the one condition to assign the vehicle ID. If the centroid of the new vehicle is within the bounding box of a vehicle Z of the previous frame and the centroid of vehicle Z of the previous frame is inside the bounding box of the new vehicle. If both these conditions are satisfied then the new vehicle is assigned the same vehicle ID as they are the same vehicle. If the new vehicle is not from the previous frame, then a new vehicle ID is assigned to it. As soon as the base of a vehicle touches mark1 the vehicle is tracked along with tracking ID by the help of centroid tracking and entry time is noted and when the base of the vehicle touches mark2, the exit time is noted. Based on the mark gap distance, entry and exit time, the speed is calculated using the simple formula given in eq. (1). This data will be sent to the firebase server and also used by the license recognition program running in parallel. If the camera is brought lower, the mark gap distance can be increased. Consequently, the accuracy of speed estimation will also increase. Flowchart of overspeed vehicle detection demonstrates the complete approach in a better way. (Fig. 4)

$$speed = \frac{markgap}{t2 - t1} \tag{1}$$

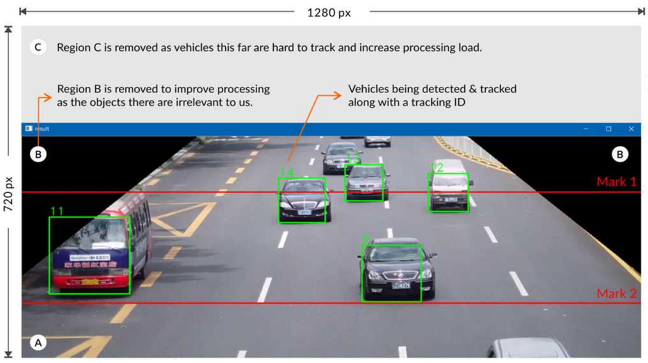

Fig. 3. Approach for speed detection of the vehicles

In this system, Firebase is used as a cloud storage platform. Firebase is a mobile application development platform developed by Google that can be used to build, improve, and grow any application. When a vehicle breaks the maximum speed limit, then our system stores the image of that vehicle, speed, date and time in the firebase server. Maximum allowed speed limit varies by country, by state and by vehicle type [16]. For testing purposes, 20 kmph to 60 kmph vehicle speed videos are used. Proposed method is able to work efficiently upto 125 kmph speed and it also depends on the processing power of the used hardware.

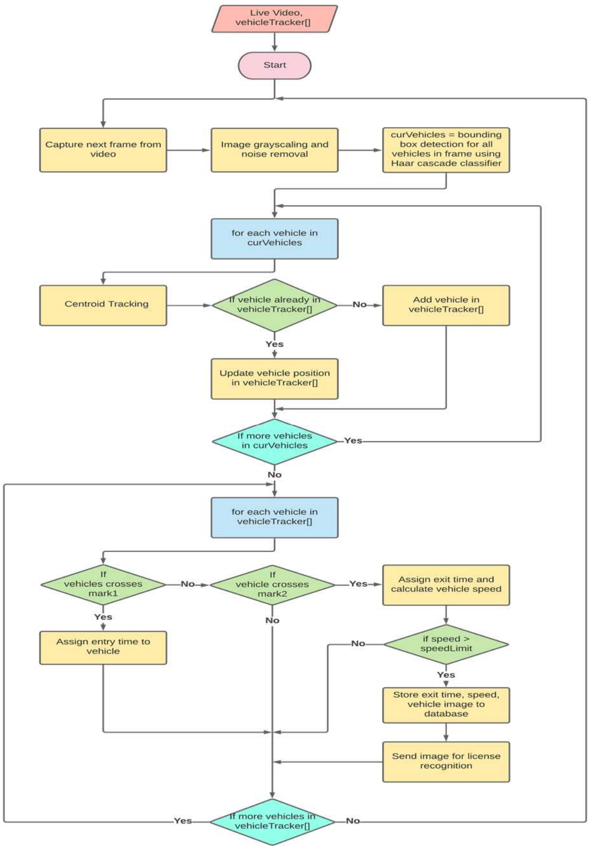

Fig. 4. Flowchart of overspeed vehicle detection

Our system processes overspeed vehicle image for license plate recognition and extracts the license number of that vehicle. OpenCV and the tesseract library is used for the extraction of license plate. OpenCV is an open-source machine learning and computer vision software library. OpenCV provides a platform to solve the real-time computer vision problems and it also accelerates the use of machine perception in the commercial products. OpenCV contains interfaces for many programming languages such as Python, C++, Java and MATLAB, it also has support for many operating systems like Windows, Android, Linux and Mac OS. OpenCV contains more than 2500 optimized algorithms, it contains plenty of machine learning and computer vision algorithms. On the other hand, tesseract is used to extract text from images. Tesseract is an optical character recognition (OCR) tool developed by Google. System uses pytesseract library which acts like a python wrapper for tesseract. By using tesseract, system can extract text from all types of images jpeg, png, gif, bmp, tiff, and others. Approach of license number extraction from a vehicle image (Fig. 5A) is given step by step:

a. First of all, system grayscale the image. System converts the image to one channel from three channel, this preserves the pixel intensities, reduces the size and make it easier to work. (Fig. 5B)
b. Then system blurs the image using a bilateral filter and reduces noise. The advantage of using a bilateral filter instead of a normal filter is that it preserves the edges of the image. That is exactly what we want for contour detection. (Fig. 5C)
c. Now, system detects the edges of the image based on the median value of the pixel intensities. (Fig. 5D)
d. Now, system detects all the contours. System takes those contours into account, whose perimeter is greater than the predefined threshold. (Fig. 5E)
e. Now, for each contour, system takes its convex hull (smallest bounding polygon for contour). (Fig. 5F)
f. Now system checks, among all the convex hulls that system has obtained, which can actually be license plate. For this, system checks the following conditions:
    - ✓ System checks whether that convex hull is approximated as a quadrilateral or not.
    - ✓ System checks whether a quadrilateral is almost a parallelogram or not. For this, system finds the length of all the 4 sides of the quadrilateral.
    - ✓ Then system checks that opposite sides are similar in length to each other or not.
    - ✓ Then system checks that ratio of the sides of the parallelogram is similar to the size of a license plate or not.
g. If a convex hull satisfies all these conditions, then it is a probable license plate. (Fig. 5G)
h. Now system converts the transformed probable license plate images into black and white so that the text on the license plate can be easily identified and recognized. Perspective transformations are also applied to flatten the probable license plate image.
i. Now system performs the binarization operation such that the text would be black and the background would be white. (Fig. 5H)
j. In this final procedure, system loop over all the probable license plates, and try to recognize the text on them using tesseract, the one with the longest text

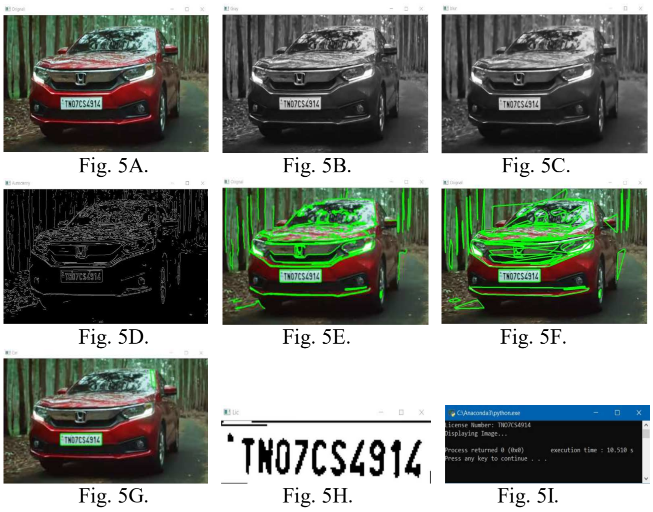

Fig. 5A. Fig. 5B. Fig. 5C.
Fig. 5D. Fig. 5E. Fig. 5F.
Fig. 5G. Fig. 5H. Fig. 5I.

Fig. 5. Steps in license plate recognition of a vehicle image

will be license plate and corresponding text will be the license number. (Fig. 5I)

Flowchart of license plate recognition demonstrates the complete approach in a better way. (Fig. 6)

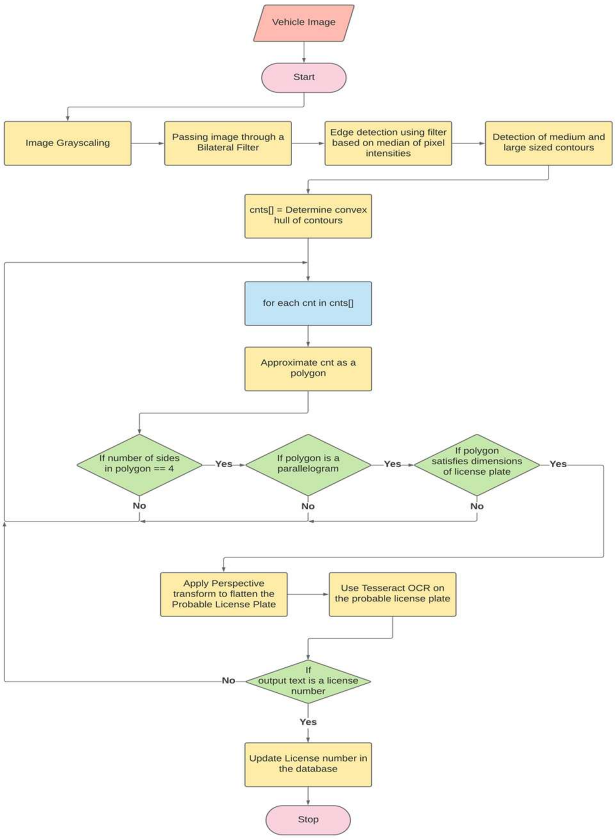

Fig. 6. Flowchart of license plate recognition

Twilio is used in the system to send SMS. When a vehicle breaks the maximum speed limit, contact details of the vehicle owner are fetched from the database using license plate number and a message is sent by system to the owner of that vehicle and the nearby traffic police station. (Fig. 7)

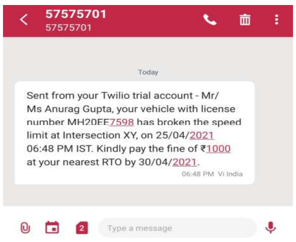

Fig. 7. SMS format to vehicle owner

If a vehicle breaks the speed limit, vehicle information is also reflected on the web page. Web page shows date and time of overspeeding, speed of vehicle along with license plate number and image of vehicle. (Fig. 8)

IV. Result And Analysis

A. Result of Overspeed Vehicle Detection:

For the verification of efficiency, system has been tested on many video feeds. System was able to track almost every vehicle on the road with more than 95% efficiency. System

SERIAL NO	DATE	TIME	SPEED KMPH	LICENSE NO	ERROR	IMAGE
1	2021-03-21	00: 48: 06	46.42	CHO4L1700	0	VIEW
2	2021-02-24	11: 11: 44	44.3	CHO4L1700	0	VIEW
3	2020-09-29	04: 51: 46	40.81	CHO4L1700	0	VIEW
4	2020-07-26	12: 03: 56	22.1	CHO4L1700	0	VIEW
5	2020-05-27	21: 01: 35	51.27	CHO4L1700	0	VIEW
6	2020-05-27	18: 02: 51	51.35	CHO4L1700	0	VIEW
7	2020-05-27	17: 53: 21	149.61	CHO4L1700	0	VIEW
8	2020-05-27	17: 40: 06	155.15	null	1	VIEW
9	2020-05-27	17: 39: 07	154.34	CHO4L1700	0	VIEW
10	2020-05-27	17: 38: 15	156.06	CHO4L1700	0	VIEW
11	2020-05-27	17: 37: 27	155.42	CHO4L1700	0	VIEW
12	2020-05-27	17: 35: 11	152.29	CHO4L1700	0	VIEW
13	2020-05-27	17: 31: 15	155.53	CHO4L1700	0	VIEW
14	2020-05-27	17: 26: 13	155.6	CHO4L1700	0	VIEW
15	2020-05-27	17: 17: 22	153.58	CHO4L1700	0	VIEW

Fig. 8. Overspeeding details view in webpage

was able to perform speed detection and overspeed vehicle detection with less than 5% relative error. Maximum speed vehicle that our system can detect and track, depends on the processing power of the hardware used for simulation. System also performs well in case of congested roads with a lot of vehicles. (Fig. 9)

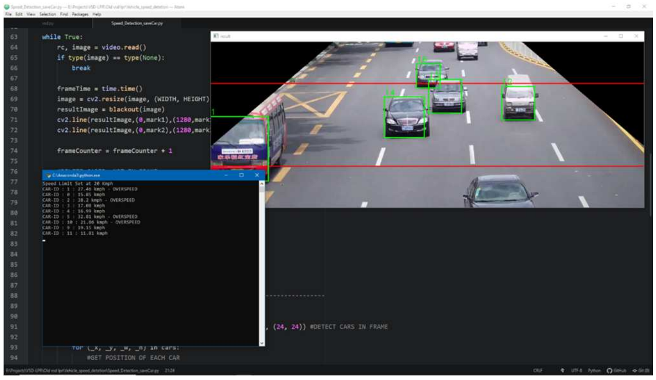

Fig. 9. Detection and speed estimation of vehicles

B. Result of License Plate Recognition:

For the verification of efficiency, license plate recognition method has been tested with large datasets and also with images which contain characters which have some similarities as for example ‘D’, ‘O’, ‘0’ and ‘8’, ‘B’ and ‘5’, ‘S’. Efficiency of the license plate recognition highly depends on the quality of provided video feed; this solution requires a good quality video feed of the road with high resolution. System performs well in most of the cases and testing results indicate that the system was able to extract license number with more than 80% accuracy. This accuracy is also the same in case of tilt license plate images, wet licence plate images and on sunny days. Proposed system makes use of perspective transformation to overcome the problems caused by tilted license plates. (Fig. 10)

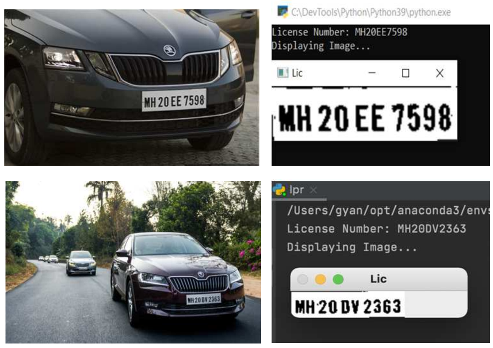

Fig. 10. Images of vehicles and license number extraction

C. *Result of Overspeed Vehicle Detection and License Plate Recognition:*

In the proposed system, vehicle speed detection, data uploading in server, license plate recognition run in parallel using multithreading (Fig. 11). For the verification of efficiency, overspeed vehicle detection and number plate recognition method has been tested on many video feeds. System performs well in almost every situation even in case of congested roads with a lot of vehicles in close range. System successfully detects overspeed vehicles, upload data to the firebase server, extract license plate information and send a message to vehicle owner and nearby traffic police station regarding this. It is also found that system performance is not affected by weather conditions and external noise. Testing results demonstrate that efficiency of the integrated system is more than 80% in almost all possible cases.

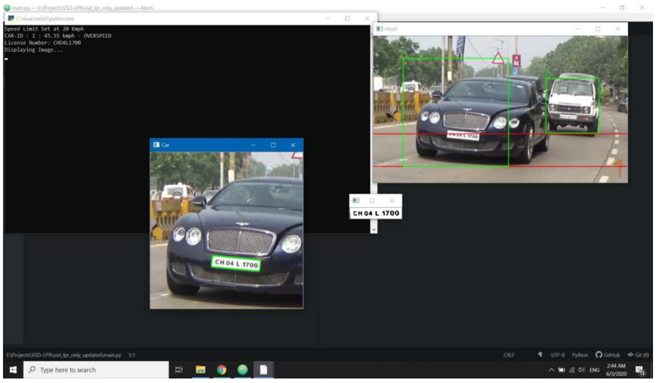

Fig. 11. Overspeed vehicle detection and license plate recognition in a video feed

V. Conclusion

Traffic management system is one of the many domains of a smart city wherein significant research can be seen. This paper presents a computer vision based approach for overspeed vehicle detection in Smart Traffic System (STS). For a cost-effective solution, computer vision based approaches have been found efficient and more reliable than hardware-based approaches. The hardware-based approaches were completely dependent on microwave sensors and lasers, apart from being expensive, they produce inaccurate results in most cases, and in addition to that their working is gravely affected by weather conditions and external noise. Even in existing computer vision based solutions, trying to estimate instantaneous speed requires extreme computational power which is not feasible for a low-cost solution. Thus, we decided to detect vehicles using the Haar cascade classifier and estimate the speed based on a 'mark gap' distance, which is faster, easier, and more accurate than other methodologies. Still even this solution requires a high resolution camera to provide feed of the road. The proposed approach helps to decrease cases of overspeeding and high death rates because of accidents. Experimental results verify the performance, accuracy and efficiency of the integrated system approximately 80% and it is evident that the proposed system outperforms the state-of-art model. In addition, continuous improvement and work on the remaining problems related to the field of traffic management will continue. Future work includes implementation of the proposed solution on large scales in the real world and testing the system on a wide scale to check the results. In future, we shall also try to include new emerging tools and technologies in our solution to make this more reliable, efficient, and cost effective.

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