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Computer vision based smart overspeeding vehicle surveillance system

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ABSTRACT

In India, overspeeding causes more than 60% of deaths. Therefore, we need a system that tracks the median speed of cars and identifies those who regularly violate the law. Road fatalities can be reduced as a result of maintaining law and order. In this paper, we present an embedded system that can read the license plates of passing cars in real time. Using optical character recognition technology, the proposed system will capture images of license plates. In addition, it sends short message service (SMS) notifications regarding the highway speed of a specific moving vehicle violating the rules to the relevant authorities. By using this technique, several manual operations that were previously required to detect over-speeding automobiles with RADAR guns are eliminated. On the roadway, the device can only be operated by one operator due to its well-developed user interface. As part of this work, a downloadable database is developed which includes information about speeding vehicles as well as vehicles travelling on a roadway at the moment they are detected.

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1. INTRODUCTION

According to government statistics [1], road traffic accidents in India resulted in 1,55,622 fatalities and 4,80,652 injuries in 2022. The number of injuries reported to the police is likely underestimated since not all injuries are reported to the police. Based on various surveys, the road fatality rate in India per 1,000,000 inhabitants is 19.5. From 2001 to 2016, the number of road deaths increased by roughly 7% per year [2]. From the Transport Resource Wing report, Figure 1 displays the total number of fatalities in various states of India during 2021. Reckless speeding causes road deaths, which need to be addressed. Laws and technology can be used together to reduce highway speeding's death tolls per year [3]. As a result of receiving a short message service (SMS) alerting police to a vehicle exceeding the speed limit in their patrol area, they can take swift action against the offender. Furthermore, it would be beneficial to monitor whether vehicles violate speed limits on the road. The regional transport office (RTO) can investigate criminal activity if it has a vehicle's number plate [4]. Once this unmanned system is implemented on highways, chasing down cars exceeding the speed limit will be a thing of the past. It will reduce highway patrol vehicle workforce and fuel consumption [5].

With the designed system, traffic police can significantly reduce the difficulty of catching overspeeding vehicles. It will be easy for the police to take necessary lawful actions to ensure road safety and keep overspeeding to a minimum when they receive a message containing the car number plate and the speed at which it was traveling [6]. Furthermore, the RTO will be able to monitor vehicles passing through the highway and their speeds with databases of all vehicles moving on the highway, as well as those that are overspeeding [7].

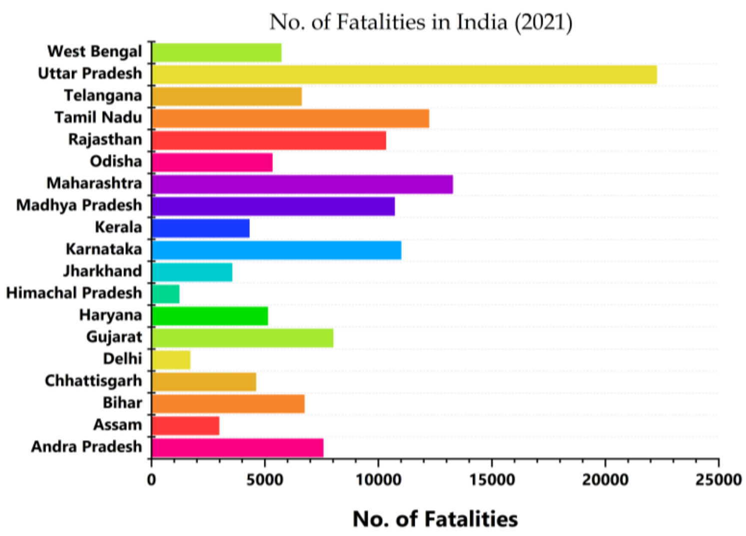

Figure 1. Total number of fatalities by significant states in India during 2021

The automatic number plate recognizing system (ANPR) was developed by the British Police Scientific Development Branch in 1976 [8]. By 1979, prototype systems were working, and contracts were made to produce industrial systems, first at EMI Electronics, and then at computer recognition systems (CRS) in Wokingham, UK. There are two types of ANPR systems: fixed and mobile. Fixed systems are installed at toll booths, border crossings, and strategic points along highways [9]. In a mobile ANPR system, the ANPR system is carried by a vehicle. Using it, you can scan the number plates of vehicles. Tracking suspicious vehicles is done by police using this approach. In places like malls, highway tollgates, and for security purposes, ANPR systems are used to track visiting vehicles. On highways, speed detection is traditionally done by RADAR guns, as shown in Figure 2, where authorized personnel point the gun toward a moving vehicle suspected of speeding [10]. For this investigation, number plate recognition was not used. Furthermore, the police should try to catch up with the vehicle. In other parts of India, speed detection is based on image processing, but again no ANPR could be implemented [11]. When a red light is flashing, police examine the captured image to find the car.

Figure 2. Radar guns to detect vehicle speed

Algorithms in computer vision and character recognition play an important role in number plate recognition and identification [12], [13]. The proposed method would eliminate all efforts to ensure road safety and follow laws. The system detects speed automatically, and the number plate checks if the speed exceeds the limit [14]. It maintains a database of vehicles for the state RTO to use in the future. Whenever a vehicle is spotted speeding and SMS will be sent to the nearest police station [15]. In this way, a vehicle can be stopped at the next checkpoint or toll gate on the highway to take the required lawful action [16]. Table 1 illustrates the comparative analysis of various existing methods.

Table 1. Comparison table

Ref	Methodology	Extraction	Segmentation	Recognition	Database	Image feature	Accuracy (%)	Real-time	Number plate Format
[17]	CNN, MobileNet, ResNet	ALPDR model	Contours	Haar cascade	Indian License plate dataset	Various conditions	89.5	x	Indian
[18]	AI	OpenCV and Python library	py-tesseract package	Template matching	Various images	Backdrop lightening	84.3	x	random
[19]	Deep Learning	Pixel Projection in Vertical and Horizontal directions	Closed curves	Template Matching	7650 images	Various lightening conditions	87.36	√	Indian
[20]	Computer vision and ML, ResNet	Bounding box	Vertical edge detection	Template Matching	AOLP dataset	Various conditions	82.6	x	Spain
[21]	R-CNN	Feature extraction	Character segmentation	Optical character recognition (OCR) method	1260 images	Backdrop lightening	86.7	x	Indian
[22]	Vision Assisted	Plane extraction	Background subtraction	Region of interest (ROI)	730 images	Various lightening conditions	81.5	√	Indian
[23]	Yolo V5	Feature extraction	Plate segmentation	OCR method	500 images	Indian lightening conditions	79.84	√	Indian
[24]	Computer vision	RGB extractor	Closed curves	OCR approach	1350 images	Different timings and distances	84.6	√	Indian
[25]	Yolov8 and EasyOCR	Feature extraction	Plate segmentation	OCR approach	Various images	Various conditions	91.87	√	Indian

2. PROPOSED METHOD

Reducing road accidents and enforcing traffic laws on Indian highways is a critical priority. However, overspeeding vehicles often evade interception by police or highway patrol due to limited enforcement capabilities and insufficient infrastructure. The proposed system addresses this gap by accurately detecting vehicles that exceed speed limits and automatically alerting nearby enforcement units for timely intervention. This enables patrol teams at intermediate checkpoints to stop violators and take appropriate action. To achieve this functionality, the system is structured into four key modules. It employs a combination of OCR-based automatic number plate recognizing system (ANPR) and speed detection algorithms. When a vehicle passes sensor 1, a camera captures its image and extracts the registration number using OCR techniques. Upon reaching sensor 2, the controller calculates the vehicle's speed based on the time taken to travel between the two sensors. If the vehicle is found to be overspeeding, an SMS alert is generated and sent to the nearest RTO via a global system for mobile communications (GSM) module, and the event is logged in a central database. The process is illustrated in Figure 3.

Unlike conventional RADAR gun setups, which cost between ₹1.5 to ₹3 lakhs per unit and require constant manpower, this system is highly cost-effective. The prototype, comprising ultrasonic sensors, a webcam, a GSM module, a microcontroller, and basic computing components, can be built for ₹12,000 to ₹15,000, with potential cost reductions in large-scale implementations. Furthermore, it operates autonomously 24/7, eliminating the need for continuous human supervision and significantly reducing long-term costs related to staffing, patrol fuel, and equipment maintenance.

2.1. Optical character recognition

The central task of the work is to detect the number plate of the car from the captured image. In addition, it converts the characters in the number plate into string data for further processing. After repeated training algorithms, characters are converted to strings in the given ROI.

2.2. Obstacle detection mechanism

Detecting vehicle presence twice is the next step in this work. In this way, speed can be calculated based on the time gap between detections. As a result of the first sensor's detection, a signal is sent to the camera to capture the number plate of the vehicle. The work involves converting characters in an image into string variables. Numerous algorithms have been proposed for detecting number plates using OCR. The system detects number plate characters in two ways.

There are two ways to do it:

a. Whenever an image is captured, the region of interest must be manually selected to ensure high accuracy. Even so, an employee must manually select the ROI whenever an image appears on the User Interface (UI).
b. Number plate localization using automatic detection of number plate characters without human intervention. To scrape out the number plate characters, many image processing algorithms are used, which reduces accuracy. This method takes into account illumination, number plate background, and everything else. However, the proposed method achieved an accuracy of 92.6%.

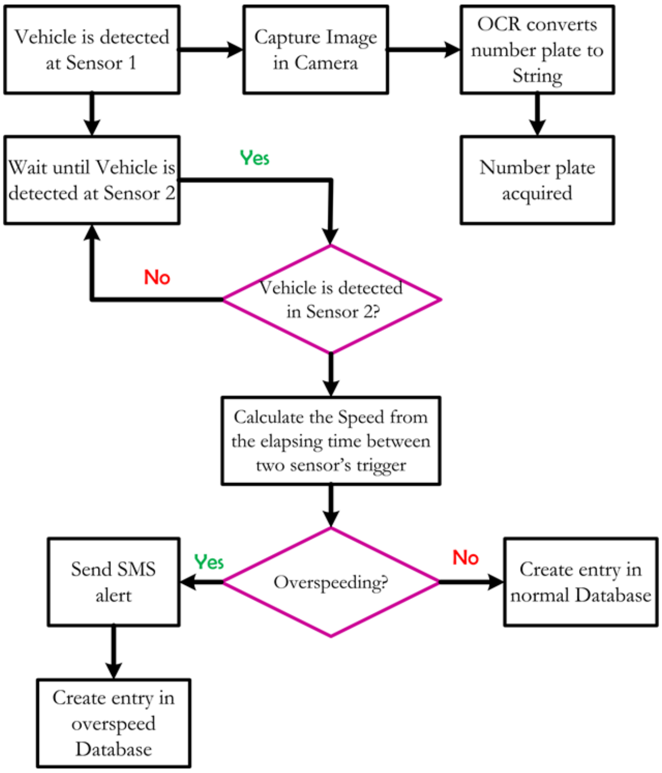

Figure 3. Block diagram of the proposed system

APNR is a form of OCR. It extracts textual information from a digital image, which consists of 0 to 9 digits and alphabets A to Z. As a result of its advanced functions for reading mixed fonts, the OCR module is suitable for recognizing number plates. Additionally, it includes characters that are not written on straight lines as well as numbers and letters written on the same line. National instruments (NI) vision assistant can be used to recognize license plate numbers. Figure 4 illustrates the optical character recognition algorithm. OCR divides a picture of a written character into segments to determine whether a region is empty or not. Based on the typeface or script of the letter used for the letter, the checksum of the resulting matrix is then identified (at least initially) as relating to the character in the image. The acquisition is used to get non-editable text from flatbed scans of corporate archives, security footage, and mobile imaging devices.

In preprocessing, noise is removed or reduced from source images at the aggregate level to make text easier to read. The process of segmentation and feature extraction involves searching the image content for clusters of pixels that are likely to represent individual characters and categorizing them accordingly. The machine learning framework will attempt to generate characteristics for the recurring pixel clusters it detects based on generalized OCR templates or earlier models. Verification by humans will be required later. Following the definition of all features, the data can be processed in a neural network training session, during which a model attempts to create generic image-to-text mapping.

Following the processing, humans review the results, and any necessary modifications are included in the next round of training. It is necessary to examine the quality of the data. It is possible to create a decent algorithm with minimal preprocessing through the use of de-skewing, high contrast processing, and other valuable methods, but more laborious data refinement may be necessary later on. It is time-consuming and expensive to clean data. Figure 5 shows step-by-step images that illustrate the implementation of the algorithm on the sample image. Before OCR is performed, optical characters are trained. Vision assistant includes training algorithms. Accurate output is ensured by character training. Step-by-step images can be seen in Figure 5(a) to 5(g): image acquired, colour threshold image, morphological filtering, filling holes, mask, masked image, and OCR.

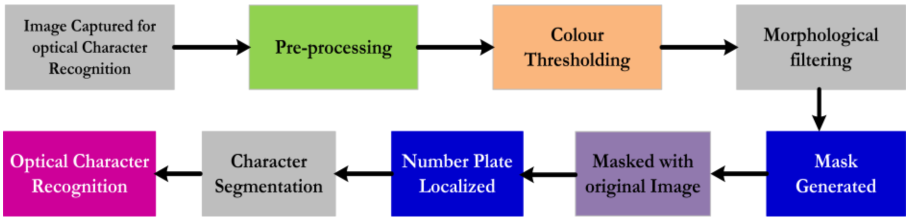

Figure 4. Block diagram of the OCR algorithm

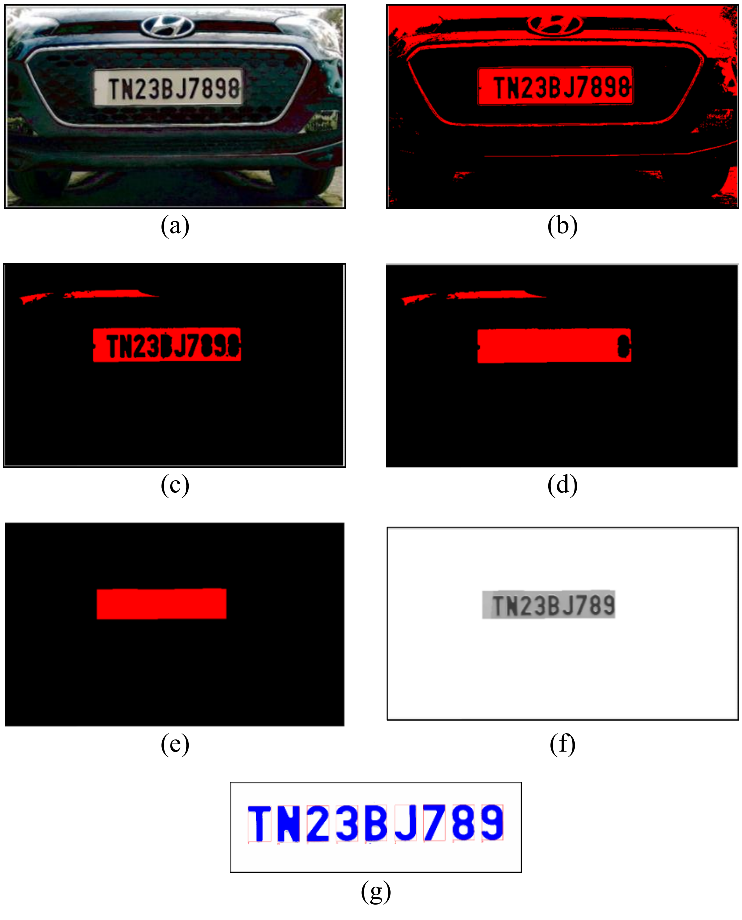

Figure 5. Step-by-step images that illustrate the implementation of the algorithm on the sample image (a) image acquired, (b) colour threshold image, (c) morphological filtering, (d) filling holes, (e) mask, (f) masked image, and (g) OCR

2.3. Obstacle detection mechanism

The speed of a vehicle on the highway is determined by ultrasonic sensors. There is an ultrasonic sensor buried within the highway, which has transmitters and receivers pointing upwards. Whenever vehicles pass over it, they generate the ECHO pulse at the echo pins from reflected waves from the vehicle base. In this work, the HC-SR04 sensor is commonly used to measure the distance between obstacles, but the reflected echo is all that is required to start and stop the timer. Figure 6 shows the basic setup for installing sensors on the road.

The speed of sound in air is 340 m/s. The ground clearance of the vehicle determines how long the transmitted wave must travel back to the receiver. When a vehicle is detected, this occurs. The ultrasonic wave took twice as long to reach the receiver as it would have taken between the transmitter and the obstacle. As a result, when calculating the distance to an obstacle, we divide it by 2. The distance between the sensors is an experimental result. On a highway, suppose vehicles average 70 km/hr. It is possible to manually calculate the distance between the sensors incorporating speed limits from 10 km/hr. to 180 km/hr. Time is measured in milliseconds using a millisecond timer. We assume a maximum speed of 180 km/hr. and a minimum speed of 10 km/hr. Currently, full-class sedans can reach a length of 2.5 meters. A car cannot be detected by both sensors simultaneously when it is 5m away. Figure 6 shows the basic block diagram showing the sensors working with the timer.

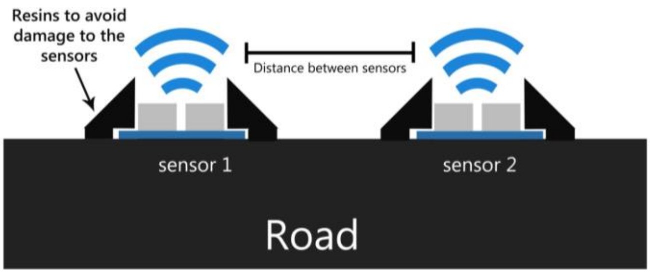

Figure 6. Setup for the sensors

2.4. SMS generation using GSM

When a vehicle is detected exceeding the speed limit, the system generates an SMS alert directed to the police or highway patrol using GSM technology. This message includes the vehicle's number plate, recorded speed, date, and time of detection, along with the hidden location where the violation was logged. Once overspeeding is confirmed, an alert message is transmitted serially to the GSM module (SIM800L) via an RS232 interface. The transmission consists of AT commands necessary for message formatting and delivery, as outlined in Table 1. The commands, along with the vehicle details, are stored in a text file that is read line-by-line by the GSM module and transmitted through the serial interface. A sample of such a file is shown in Figure 7. The LABVIEW virtual instrument (VI) handles communication through the COM port (via USB to RS232 converter), sending each line of the command file. The system is configured to transmit up to four iterations per overspeeding event to avoid redundant messages. In the absence of a violation, the text file remains blank and no SMS is sent. The SIM800L module, requiring a SIM card, can send SMS to a single designated number in international format (*e.g.*, +91 for India). Typically, the GSM module takes 4–6 seconds to initialize and send an SMS after detection. During testing, a 98% delivery success rate was observed under stable network conditions. Delays beyond this window were primarily due to weak signal or network congestion—known limitations of GSM networks. To mitigate this, a retry mechanism was implemented within the LABVIEW interface, allowing up to four message attempts per event while preventing duplicate alerts.

2.5. Generation of databases

In this project, a dual-database system is developed: one for logging all vehicles passing through the highway and another specifically for overspeeding vehicles. These databases are generated using LABVIEW's FILE I/O toolkit and are stored locally as text files on a password-protected computer. To ensure data security, access to these files is limited to authorized personnel through operating system-level user permissions. The alert system is designed to detect and report overspeeding incidents on Indian highways using a combination of ultrasonic sensors, cameras, and OCR algorithms. When a vehicle crosses the first ultrasonic sensor, it triggers a camera to capture a front-facing image. Upon detection by the second sensor, the system calculates the vehicle's speed using the time difference between the two sensor activations. The captured image is then displayed in the LABVIEW-based user interface, allowing even non-technical operators to manually select the region of interest (ROI) for OCR processing.

If the system identifies the number plate and determines that the vehicle is overspeeding, an SMS alert is automatically sent to the police via the integrated GSM module. Importantly, the system collects only essential data—vehicle registration numbers, speed, date, and time—without storing any personally identifiable information (PII). For data retention, logs can be auto-archived on a monthly basis, with deletion schedules set according to institutional or government data handling policies.

It takes no time at all to generate a database with the updated entry of the car. The speed at which it travelled is also included. There are several essential features of the project, including:

a. In addition, there is a well-organized USER INTERFACE that displays real-time vehicle images, detected speed, extracted license plate text, overspeeding alerts and log of recent events that a non-technical person can easily understand.
b. The interface includes visual indicators (LEDs) and simple action buttons, ensuring that users with minimal technical background can operate the system. The ROI selection for OCR is semi-automated but can also be manually adjusted using mouse input if needed.
c. The GSM module generates messages automatically without requiring user input. By using a serial-to-USB converter, any fault in the module can be quickly repaired.
d. There is no way to damage hardware units until physical damage occurs; thus, all hardware units are out of reach of the operator.
e. Regarding training, a brief 1–2 hour session is sufficient for operators to learn system startup, data handling, and SMS monitoring procedures. The interface also provides error prompts and confirmation messages to guide users.

The following are additional features:

a. Printable databases are created in .txt format.
b. In case of damage, all parts are easily replaceable. Among its components are the camera, the microcontroller, the sensors, and the GSM module.

A database is generated by the software that records all vehicles traveling on the highway and those overspeeding. Each entry in the database contains the vehicle number plate, speed, date, and crossing time. For further referrals, these can be transferred as Excel sheets or printed for retention by the RTO or National Highways Authority of India (NHAI). LABVIEW's FILE I/O toolkit is used to generate the databases. As shown in Figure 7, each entry is entered whenever a satisfactory number plate length is detected. When creating entries, it is important to take caution. Suppose the database generator code takes too long to generate each entry. In that case, the database may contain duplicate entries more than once, which is unprofessional. A few seconds delay is allowed for the generator to run when an entry needs to be saved for checking. Uncontrolled runtime execution ensures that no two entries are repeated.

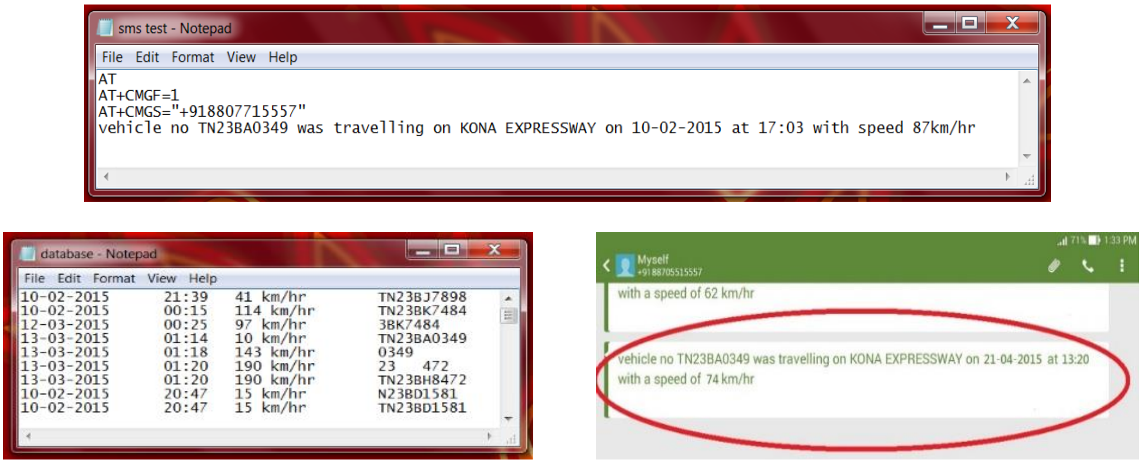

Figure 7. Sample text file for sending a message in an over-speeding case and database maintenance

3. RESULT ANALYSIS FOR VARIOUS SCENARIO

The proposed method is primarily intended for deployment on highways, where accurate vehicle speed and license plate detection are crucial. Due to hardware and testing constraints, a compact prototype platform was developed, integrating essential components without compromising core functionality. To ensure precise image capture during vehicle motion, a high-resolution camera with optimized lighting was employed, minimizing motion blur and ensuring clear number plate images.

Although full-scale testing on actual highways was not feasible, the system was evaluated under comparable conditions using scaled components. For reliable ultrasonic sensor readings, a hard plastic lid was used to simulate a vehicle, as soft materials—such as sponges or human palms—dampen ultrasonic reflections and reduce detection accuracy. Since obtaining high security registration plates (HSRP) from the

RTO requires official clearance, sample plates were instead used during testing. Two categories of number plate images were analyzed. The first involved real vehicles captured in real-time using a high-resolution camera in Figures 8(a) and 8(b), while the second involved printed number plates on high-quality paper photographed by a webcam in Figures 8(c), 8(d), and 8(e). This allowed the system to be tested in both ideal and practical conditions. Despite using a basic VGA webcam for the second category, the OCR system was designed to maintain consistent recognition performance. Figure 9 shows the LABVIEW-based user interface developed for real-time testing and monitoring.

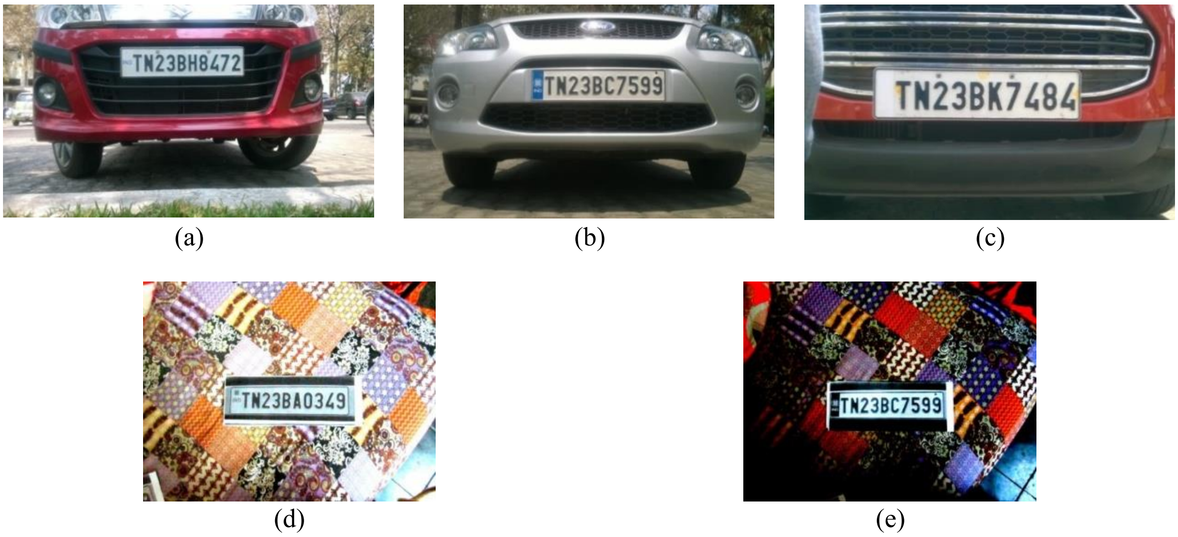

Figure 8. Different types of number plates considered for the analysis (a) and (b) real vehicles captured in real-time using a high-resolution camera; (c), (d) and (e) printed number plates on high-quality paper photographed by a webcam

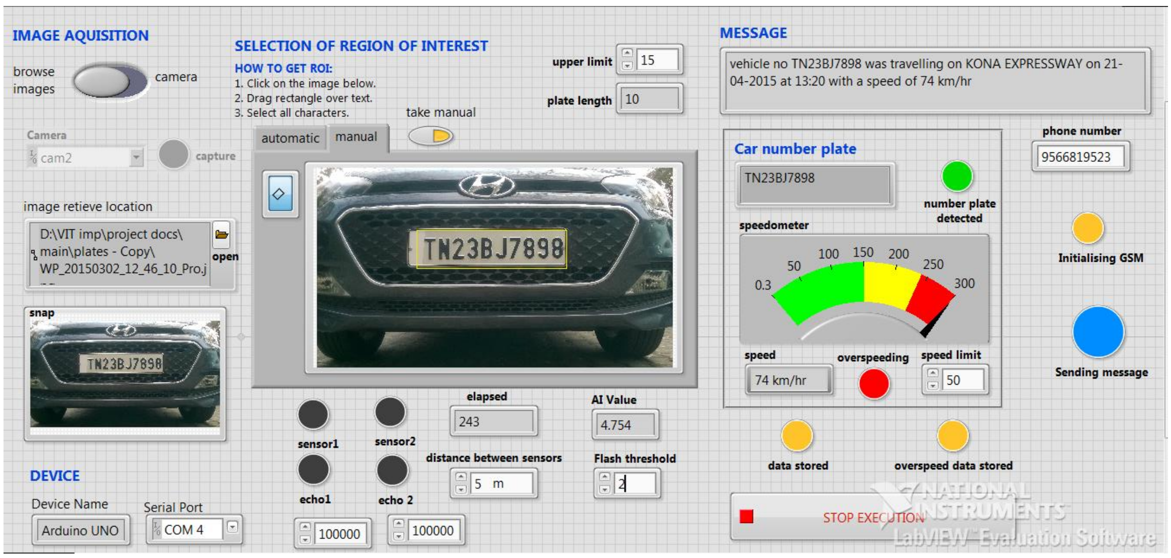

Figure 9. The user interface for the project

To enhance image clarity before OCR, preprocessing techniques—including morphological filtering, hole filling, and contrast enhancement were applied. The OCR engine was trained using custom datasets of Indian license plates, accounting for font variations and diverse lighting conditions. Post-recognition, a character validation layer ensured format compliance (*e.g.*, flagging alphabetic characters where digits are expected), enabling manual review when needed. Overall, the system demonstrated stable and accurate performance across real-time constraints. The prototype achieved an OCR accuracy rate of

92.6%, with most errors occurring under suboptimal lighting or imaging angles. Future improvements will explore deep learning-based OCR models and redundant frame analysis to minimize false detections. The results indicate that while industrial ANPR cameras could further boost accuracy, the current solution offers a promising, cost-effective approach for real-world highway monitoring.

4. CONCLUSION

The developed prototype accurately detects vehicle speed and number plates, while generating reliable, error-free databases. The GSM alert system operates as intended, consistently issuing notifications when overspeeding events are detected. This establishes a solid foundation for intelligent traffic monitoring; however, there remains considerable scope for enhancement, particularly in areas such as obstacle detection and image processing. Improvements like advanced number plate localization and automatic ROI extraction can further optimize performance. Currently, the system does not handle adverse environmental conditions such as heavy rain, fog, or low-light scenarios due to hardware constraints. These limitations are acknowledged as critical challenges for real-world deployment. Future iterations may incorporate technologies like infrared imaging, adaptive thresholding, and deep learning-based OCR to improve robustness in such conditions. In terms of data governance, privacy and security remain top priorities. Upcoming versions will include encryption mechanisms, secure remote access capabilities, and full compliance with Indian data protection frameworks, including the digital personal data protection act, 2023. To combat potential misuse, planned features also include fake plate detection through image forensics, consistency checks across checkpoints, and vehicle appearance-based tampering detection. Additionally, future developments will introduce traffic analytics capabilities, enabling the system to identify peak overspeeding hours, analyze vehicle flow trends, and map location-based violation clusters. These insights will support data-driven law enforcement and infrastructure planning. With its scalable, modular architecture, the system is well-suited for expansion into full-scale, real-world highway monitoring and traffic enforcement applications.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

No conflict of interest.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

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