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Drowsiness Detection and Alertness Using Eye Motion Monitoring

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Abstract

The driver felt sleepy when they don't take proper rest while driving on long routes. Restless driving leads to careless mistakes which could be fatal to the driver as well as others' lives. This issue has been increased to such a level that a system is required to avoid accidents and save a life. Driver alertness detection can play a significant role to avoid such hazards. The system can identify the drowsiness on the face of the drivers and can generate an alarm for them to stop or take necessary actions. Eye state analysis is a key step for alertness detection that helps to identify the state of the eye whether it is open or closed. In this paper, the method has been proposed for eye state analysis following face and eye detection to detect the driver's alertness. This system has been integrated into four steps; including detection of the face, detection of the eye, analysis of eye state, and decision regarding driver's drowsiness. A warning signal has been buzzed on drowsiness detection to alarm the driver. Simulation results validate that our proposed idea attains high accuracy and low error rate as compared to the state-of-the-art.

Index Terms: *Alertness Monitoring System, Drowsiness Detection, Euclidean Distance Classifier, Traffic Accidents, 68-Face Landmarks Algorithm.*

I. INTRODUCTION

The number of traffic accidents in every country is found rapidly increasing as the number of automobile vehicles is increasing exponentially day by day. Statistics show that most of these fatal accidents are the result of a diminished level of vigilance of a driver. Therefore, these accidents have undoubtedly become a cause of serious concern to society. Drivers with impaired alertness cannot perceive threats resulting in the loss of vehicle control which poses a danger to the lives of people. According to statistics, 57% of truck accidents occur due to the fatigue or distraction of a driver, and 68% of the drivers in America are reported fatigued. However, at this rate, the problem can lead to serious damage in the future. For this reason, a robust and non-intrusive system needs to be developed that continuously monitors the driver's alertness level which can warn the drivers when any unsafe condition like fatigue and drowsiness is detected. This can play a significant role in accident prevention. But the real-time and non-intrusive detection based on facial features is a challenging task in designing a robust and efficient safety system in automobile vehicles. Therefore, our proposed system solely focuses on the detection of driver's fatigue level and vigilance in automotive vehicles. Considering this challenge, multiple research and implementations have already been done in this field that monitors the fatigue and drowsiness level of the driver using multiple approaches [1], and [2]. Potential techniques include:

- Monitoring vehicle response.
- Monitoring driver response.
- Monitoring the physiological characteristics of a driver.

But for efficient monitoring, the most reliable approach is to consider the physiological characteristics of a driver that includes:

- Observing physiological signals like heart rate and brain waves.
- Measuring physical activities like posture, head movement, and the state of the eyes.

However, to achieve the intrusiveness and robustness of the system, a technique based on the eye state (open/closed) appears to be efficient and easily applicable to real-world driving conditions that can be achieved by using a single-mounted camera to monitor the state of the eyes. An alertness system that tracks the eye is achieved if we measure the duration of the closure of the eye by using the camera. An eye state-based algorithm is developed to detect the alertness of the driver beforehand. The driver is alerted with the help of an alarm in the vehicle. The eyelid movement of the driver is considered in the proposed system for the detection of a tired state. Sleep for a short time (1 to 4 seconds) is considered an indication of the tired state of the driver [3]. The eyes of the driver are monitored continuously with the help of a camera to obtain the state of the driver. Analysis of blinking of eye patterns, the position of eyes, and face detection are the factors for the detection of a driver's alertness. "Shape predictor containing 68-face landmarks" is used for the analysis of the face of the driver. A webcam has been used to detect the alertness (i.e., eye movement, face detection) of the driver. The focus of this project is on the opening and closure of eyes, which involves analysis of the whole face image and the detection of eyes by using the 68-face landmarks algorithm. When the correct position of the eyes is detected, we calculate Euclidean distance to check whether the eyes are opened or closed to detect drowsiness. The beep alarm is played in the eyes of the driver and is closed for a time. The alertness model is presented in this paper in which the basic techniques of machine learning and computer vision are applied for the prevention of accidents.

The paper is organized as follows; Section II describes the state of the art. Section III presents the proposed methodology. Section IV provides the software requirements. The results and their analysis are reported in Section V. The conclusions are presented in the last Section.

II. STATE OF THE ART

In this section, some papers have been reviewed to demonstrate some methods to detect fatigue/drowsiness in drivers while monitoring their alertness as a precatory measure to reduce the rate of road accidents. In 2022, researchers designed a real-time image processing system to find the alertness of a driver based on the assessment of the Eye-Aspect Ratio (EAR) [4]. To get the details of a driver a camera is used and to determine the driver's condition Computer Vision Based methods are used. The attentiveness of a vehicle driver is continuously measured by the EAR. A. In 2023, Author Shahzeb Ansari and associates proposed a real-time smart detection algorithm that analyzes the classification of driver behavior. additionally, an unsupervised deep learning neural network is utilized in this paper for classifying driver behavior and state [5].

A study that built spectacles has IR sensors and a buzzer to alert the driver whenever the driver gets drowsy and keeps his eyes remain closed for more than a second. They developed an application to inform the owner of the vehicle/company about the driving protocol via text message using the GSM module [6]. Author Y. Chellappa and his associates proposed a system for the detection of driver fatigue when the vehicle is moving [7]. The system proposed by him has some hardware components like sensors and a camera, a module for processing data, and an alert unit. Using somatic sensors, the factors that can cause drowsiness are monitored. The processing unit detects the drowsiness, and the alert unit alerts the driver. H. A. Rahim et al. proposed the idea to detect the drowsiness of drivers using heart rate or pulse sensors. These sensors measure the pulse rate from the finger of the driver and detect the flow of blood. The fluctuation in the amount of oxygen in the blood is detected and the sensor connects it to Arduino. Heart pulse is visualized by the processing of software. The result of the experiments shows that the low-to-high frequency ratio is decreased as the driver goes into a drowsy state. If the alert signal is sent on time many accidents can be avoided [8].

Zhiwei Zhu and Qiang Ji proposed a non-intrusive and real-time model to monitor drivers' alertness. This technique requires two mounted CCD cameras that are equipped with active Infrared (IR) sensors that enable real-time consecutive video frames which are systematically combined to infer the fatigue level of the driver. The proposed model is designed to monitor the fatigue of the driver based on contextual information like the eyelid, gaze, and head movement along with facial expression [9]. These simultaneous video frames carry multiple pieces of information that give accurate and robust fatigue monitoring. In 2013, G. Kong et al. proposed a model to analyze driver alertness by observing the eye state along with head posture. The proposed approach uses features like Pupil Activity (PA) and Eye Index (EI) as contextual information to infer the level of distraction and drowsiness of the driver [10]. This information is in the form of consecutive video frames that are further classified by using a Support Vector Machine (SVM) into alert or non-alert driver response. This proposed design yields a highly accurate classification with a low error rate after being trained on different genders and people of numerous ethnicities. In 2014, Eyosiyas et al. designed a technique to detect drowsiness through Hidden Markov Model (HMM) based dynamic model. This proposed technique extracts and analyzes the facial expression by using HMM which is used to infer the fatigue level of the driver. Experimental results verified the robustness and accuracy of the proposed model [11].

In 2022, D. Kumar et al. developed a method for detecting drowsiness using a CNN model. The Tiredness Detection System identifies drowsiness based on the driver's eye closure [12]. The proposed innovation can prevent drowsy-driving accidents. Even with glasses, the device works in low light if the camera output is high. Head and eye locations are determined using self-developed image-processing algorithms. The technology can detect if the eyes are open or closed. Long-closed eyes offer a warning. Continuous eye closures measure driver alertness. In 2022, K.T. Luther et al. discussed a prototype computer-vision-based system that uses an eye tracker and a camera mounted on the dashboard to keep tabs on a driver's attentiveness in real time [13]. This research aims to discover the driver's focus point. Based on this research, the driving instructor can tell what the learner looks at most. An eye-tracking application analyses the driver's gaze. It's a prototype for real-time eye tracking to assess driver focus during practice. This study examined driver attention by capturing eye movement under real road driving scenarios. In 2021, Y. Li et al. used a Millimeter-Wave Frequency-Modulated Continuous-Wave (FMCW) radar system, installed in the dashboard of a vehicle which may detect and track the driver's head and torso motions. To analyze and categorize the micro-Doppler characteristics, a spectrogram image format is created. The time-frequency characteristics of the eight distinct head motions are analyzed and described separately [14].

The systems aren't completely self-sufficient and error-free. It is difficult to determine the success rate in various lighting situations. The various systems utilize different algorithms and working methods. It would be more error-free if we could integrate every system that is installed virtually entirely from the same set of components. The installation process is frequently tedious and tedious for the drivers, who eventually lose interest. Another crucial factor to determine a driver's level of fatigue is the total number of blinks per minute. Systems that identify fatigue based on overall fatigue per minute are not very notable.

III. PROPOSED METHODOLOGY

The main objective of this paper is the development of such a system in moving vehicles, which analyzes the state of the driver's eye to check if the driver is alert or not. A system is developed for this purpose which acquires the video data from the source and divides them into different frames or images. Firstly, the face of the driver has been detected then this system detects eyes and checks if the driver is alert or drowsy. This system is developed based on the concepts of machine learning and computer vision. The driver's eyelid movement is detected using a small webcam which is mounted at some distance from the driver and pointing directly toward the driver's face to check if he is alert or not. If the driver is not alert, a signal to alert the driver is generated. The eyes are detected within the specified range of the face. If the system which extracts eyes does not find eyes for more than 30 frames continuously this system predicts that the driver is sleepy. A system is developed in this project that tracks the eyes and alerts the driver by using Python. This system consists of three phases which include sensation, detection, and correction. The steps of our proposed system are shown in figure I.

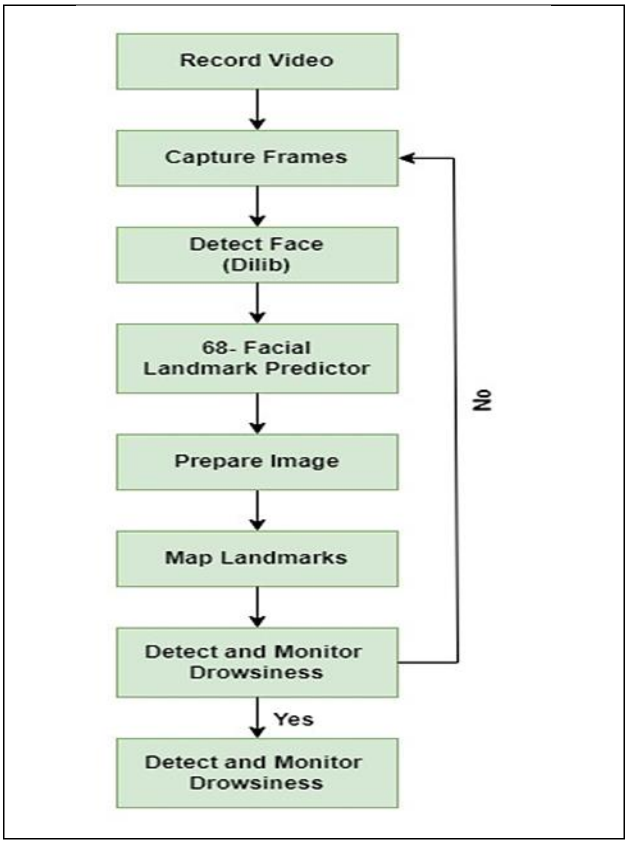

Figure I: General Flow of System

In the first phase, the video is acquired from the source using the webcam. The libraries of Python which are used for the detection of faces and eyes are 'OpenCV' and 'Dlib' with the help of 68-face landmarks. In the second phase, the analysis acquired from the previous phase is extracted to check the state of the driver. The state of eyes is detected by the calculation of Euclidean distance of eyes to check whether the driver is drowsy or alert. In the last phase, accurate action is taken against the behavior of the driver. If the driver's eyes are found close for a certain interval of time, then this is considered invalid behavior and the alarm starts playing. Besides this, it displays the message 'Sleeping'. When the eyes are opened again the same process of capturing the video goes on. The flowchart of our proposed model is shown in figure II.

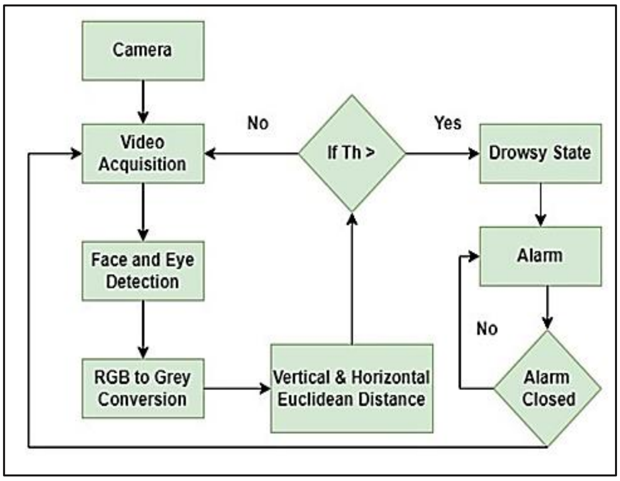

Figure II: Flow Chart of Proposed System

IV. SOFTWARE REQUIREMENTS

A. Python

Python version 3.6 is used in our project for the detection of faces and eyes. It uses OpenCV and Dlib packages for recognition purposes. It is interpreted as a general-purpose programming language. OpenCV is a computer vision library and Dlib is an open-source C++ library, used for implementing machine learning algorithms.

B. Webcam

Webcam is a video camera used to record video and broadcast it to a network. Real-time video streaming is captured using a webcam. Face and eye detection are the major concerns. Webcams are mostly used for security, streaming live and virtual communities. Wireless protocols or universal serial buses are used to connect webcams with the desired device.

C. Win Sound

For playing alarm in this project, a library 'Win Sound' is used to alert the driver for drowsy conditions. Win Sound is a module provided by Python and it gives access to sound-playing machinery. It provides several functions, i.e., 'Beep' will cause the PC's speaker to beep, 'Play Sound' will play sound, and 'Message Beep' will play a sound with a message.

V. IMPLEMENTATION

A. Detection of Face

The detection of face and eyes was carried out on the data extracted from the video captured via webcam. OpenCV and Dlib have been used to acquire '68-Face Landmarks' for the detection of faces. From these results in face landmarks, we obtained the range of the marks covering the eyes, shown in figure III below.

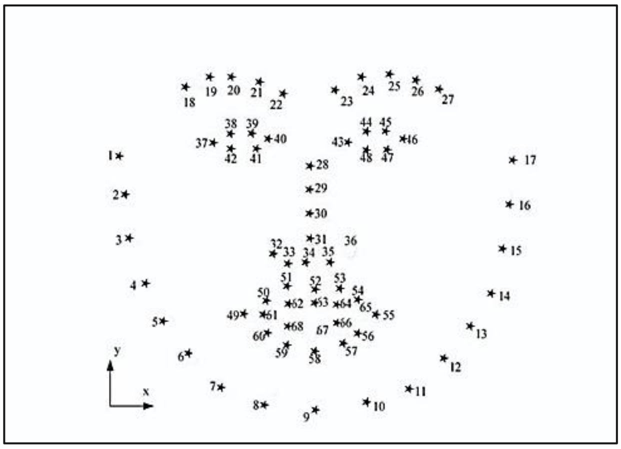

Figure III: Landmarks of Face

When the eye marks are detected correctly, further processing is done on the range of 37-42 marks and 43-48 marks which represents the right and left eye, respectively. The function of Python is given below.

face_detector_HOG=dlib.get_frontal_face_detector () facelandmark_dlib=dlib. shape_predictor "shapeprd-ctor_68_face_landmarks.dat\")

B. Detection of Eye

After identifying the face and eyes, the image is converted into a grayscale image to perform further processing. Using the detected 68-face landmarks, the sides, as well as the center of the face, were found to help as a reference for the comparison of the right eye with the left one. The average face area in a horizontal direction has been calculated while moving downward from the top of the face. The formula for the calculation of the average face area in a horizontal direction is shown in eq. (1). Similarly, Euclidean distance has been used to calculate the distance from the vertical and horizontal distinctive points of an eye area, as specified in figure IV.

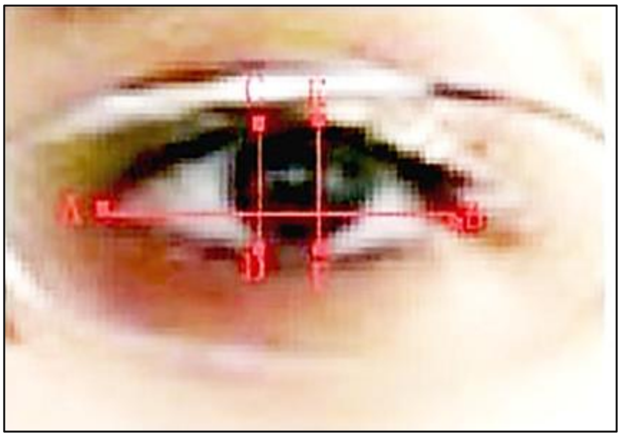

Figure IV: Euclidean Horizontal and Vertical Distance

The calculated distance is used to identify whether the eyes are open or closed. Euclidean horizontal and vertical distances identify the eyes that are opened or closed by comparing them to the set threshold. If the resulting distance is greater than the set threshold, the eyes would be considered as open if not then closed. Thus, to be aware of the driver's alertness and vigilance, Euclidean distance played an essential part. The formula for the calculation of Euclidean distance is given in eq. (2).

$$\text{EAR} = \frac{|CD| + |EF|}{2 * |AB|} \qquad (1)$$

Here:
Symbols A and B are representing horizontal distance while C, D, E, and F are representing vertical distance.

The formula for the calculation of Euclidean distance is as follows:

$$d = \sqrt{}\ (x1 - x2)^2 + (y1 - y2)^2 \qquad (2)$$

C. Python Function

A= distance. Euclidean (eye [1], eye [5])
B= distance. Euclidean (eye [2], eye [4])
C= distance. Euclidean (eye [0], eye [3]) ear_aspect_ratio= (A+B)/ (2.0*C)
print (\"Sleeping\")

We have used the 'Win Sound Library' to play the alarm, if the eyes of the driver stayed closed for the time of one second then the message 'Sleeping' will be displayed. #Winsound. Beep (frequency, duration).

D. Action Function

Our proposed design can detect drowsiness considering different aspects like partially closed eyes, fully closed and eyes wearing spectacles. Additionally, it can detect eyes on a face at multiple angles like left and right sides facing the camera. All these functions work completely fine under low light which provides this system with an additional feature like working under poor light conditions. This system is capable of processing 30 frames per second on a computer with a 2.9 GHz processor and 800 MB RAM. Each frame is of size 280*140. The library it uses is called 'Dlib' which is for testing samples. And for classification, Dlib uses a built-in model classifier named linear Support Vector Machine (SVM) and Histogram of Oriented Gradients (HOG).
Our system can generate more than 90% accurate results even after testing on people of different ethnicity. And the reason for the error in some test samples might be because of extreme conditions like face angle or poor light. The testing result is mentioned in the following figures. As an initial step, libraries named OpenCV and Dlib are used to detect a face and eyes with the help of 68-Face Landmarks as shown in figure V. After detecting the face and eyes, the system undergoes processing to infer the information about the eyes whether they are closed or open. If eyes are found closed after processing, the system displays a message as 'Sleepy' along with a beep of an alarm as shown in figure VI. Our system displays the same result for partially closed eyes as shown in figure VII.
As shown in figures VI and figure VII respectively, our model detects the closure of an eye by displaying 'Sleeping' along with a beep and an alarm when it found the average Euclidean distance is less than the threshold value for one second.

Figure V: Face and Eye Detection

Figure VI: Complete Eye Closure

Figure VII: Partial Eye Closure

If the calculated aspect ratio is more than 0.26 which is a threshold value, then a message will be displayed along with a beep otherwise it will continue to calculate the ratio can be seen in figure VIII. The comparison is given in table I. To our knowledge, results achieved in the literature using a dual camera system by author You and associates are 83.0% [14]. An accuracy of 94.0% has been achieved by author Rehman and associates by using eye blink monitoring [15]. Using eye blink patterns, author Danishman and associates reported an accuracy of 90.07% [16]. However, our model gives an accuracy of 95.5% for both people with and without eyeglasses.

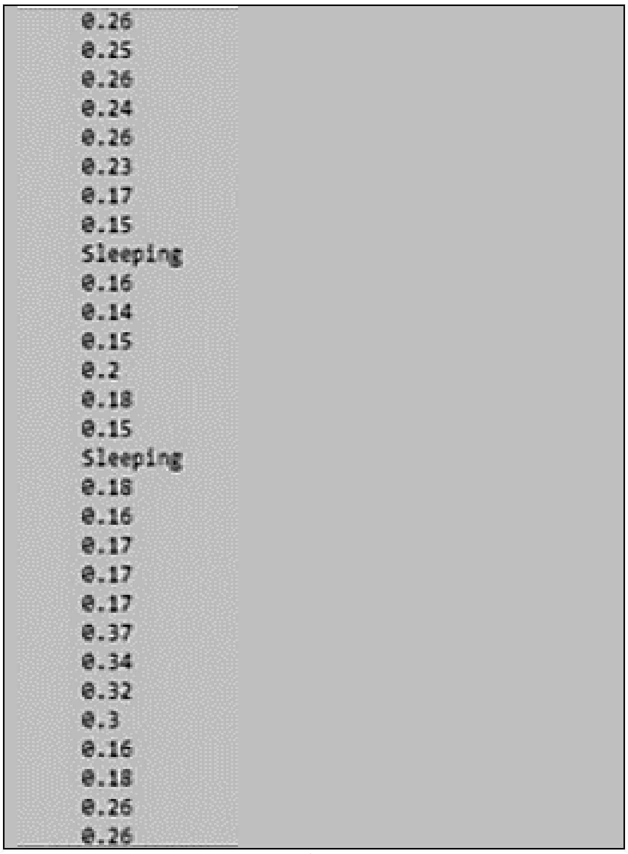

Figure VIII: Aspect Ratio of an Eye w.r.t Threshold Value

Table I: Comparison with Related Works

Approach	Accuracy	Error rate
Dual-camera System You *et al* [15]	83.0%	17.0%
Eye Blinks Monitoring Rahman *et al* [16]	94.0%	6.0%
Eye Blink Patterns Danishman *et al* [17]	90.7%	9.3%
Our Approach	**95.5%**	**4.5%**

VI. CONCLUSION AND FUTURE WORK

Our proposed system for monitoring the alertness of a driver can play a significant role in driver's safety by avoiding road accidents as it detects drowsiness based on the state of an eye beforehand. And for eyes and face detection, 68-Face-Landmarks have been used that are provided by the libraries named 'Dlib' and 'OpenCV'. After detecting the eyes and face, the state of the eyes whether open or closed is determined by calculating Euclidean distance. When the distance is found less than the threshold for one second, the eyes are considered as close, and a message is displayed with a beep sound to alert a driver. The threshold value is set as 0.26 and above for most people of Pakistan and multiple ethnicities but still, this can't be applied to all ethnic groups. This model successfully generates 95.5% accuracy. However, as the system's limitation, it fails to generate accurate results in the presence of any reflective object behind the driver and under poor light conditions.

In the future, the approach would be to develop a more autonomous system that is capable of monitoring in low light the distraction level of capturing other parts of an eye like pupil movement to avoid road accidents and ensure the safety of a driver.

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Authors Contributions

The contribution of the authors was as follows: Naveed Ur Rehman Junejo's contribution to this study was the concept, technical implementation, and correspondence. The methodology to conduct this research work was proposed by Rabia Asghar. Data collection and supervision were performed by Ahmad Hassan. Farwa Ikram facilitated the data compilation and validation. Abeera Mahfooz Cheema's contribution was project administration and paper writing.

Conflict of Interest

The authors declare no conflict of interest and confirm that this work is original and not plagiarized from any other source, i.e., electronic or print media. The information obtained from all of the sources is properly recognized and cited below.

Data Availability Statement

The testing data is available in this paper.

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