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Support Vector Machine Based Intelligent Driver Drowsiness Monitoring System

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ABSTRACT

In the modern era, the transportation is one of the most vibrant sector and lot of impetus is involved in it. Traffic load is increasing on the roads and incidents of road accidents have also increased. Driver fatigue and feeling of drowsiness thereafter, are one of the important factor resulting in accidents and subsequent deaths. There are numerous cases where the driver had dozed off for a few seconds resulting in accidents. The commercial truck drivers driving tirelessly for long hours (especially during night), are more prone to this situation. Driver sleepiness is sort of a nightmare for passengers all over the world. Every year, a variety of injuries and deaths occur due to sleepiness connected road accidents. It has led to an open area of research and many studies are carried out throughout the world and technology has been at the forefront of these important research. Detection of likelihood of Driver's sleepiness and its remedial measures by real time analytics is an important area of research in the transportation & public safety domain. Most of the traditional strategies are vehicle-based, behavioral-based, some are intrusive in nature while some need costly sensor networks and information handling. The novelty of our proposed solution, is that it is a low cost, real-time driver's drowsiness detection system with significant accuracy. In our system, a digital camera continuously records the video capturing driver's face and changes happening over time. Facial landmarks on the detected face are pointed out using Support Vector Machine (SVM) based pre-trained facial landmark predictor. From this, the eye aspect ratio is computed. Drowsiness is detected from these calculated values. If sleepiness is detected, a warning alert is given to the driver through an alarm and it conjointly sends a response to the second person who may take appropriate action. It will be furthering the research in the domain and shows the high potential of machine learning algorithms in the domain.

Key words: Drowsiness detection, eye aspect ratio, SVM, Machine Learning.

1. INTRODUCTION

While driving a vehicle, drivers must remain alert at all times and it implies focusing on the road rather than on phones, music players or any other sources of distractions. This can be minimized by following self-discipline to a large extent, but what about driving fatigue as a result of long drive hours and many other similar factors? One of the most significant reasons for road accidents is this fatigue resulting in drowsiness feeling of the drivers and as a result, they lose track of the road, and this loss of control over vehicle maneuvering for a fractional moment leads to accident. This is an open field of research and different signs or symptoms of drowsiness for an individual are understood and identified. The signs are as follows:

- Lack of focus and dreaminess feeling
- partly closed eye and increase in eye blinking frequency
- hallucination effect and confusion in recollecting the travelled path
- frequent yawning tendency
- Lane Drifting
- Head nodding
- Decreased concentration
- Slowed reactions and reflexes

The primary goal of the present work is to reduce accidents that are caused by above symptoms resulting as result of mental fatigue of drivers. In our solution this can be ascertained by a camera placed within the dashboard of the car which will continuously record the eye aspect ratio of the driver, and judge if he is closing the eyes, more often than his usual pattern and compare it to the observed pattern. This helps in understanding whether the driver is falling asleep or not and alerts the driver with an alarm for taking some rest to avoid accidents &option to message to the other person who is closer to him in order to counsel him and speak to him for safe driving.

The paper is divided into 5 sections with first being the Introduction, followed by a section on Related Works where some of the recent works are cited and discussed. The third section has a discussion on the proposed approach for drowsiness detection and monitoring. Fourth section the authors deliberate on the Results & Discussions of the work carried out by them and fifth section presents the Conclusions and Future Scope of the current study.

2. STUDY BACKGROUND

2.1 Basic Terminologies

The term "drowsy" is substitutable with sleepy, that is merely an indication of stage of falling asleep. This stage is often classified as

- awake,
- non-rapid eye movements sleep (NREM), and
- rapid eye movements sleep (REM).

NREM - the second phase is further divided into the subsequent 3 phases [2].

Phase I: going from awake stage to asleep stage
Phase II: Light- Weight sleep
Phase III: Deep sleep

These phases need to studied, observed and understood for building an intelligent prevention system for averting fatigue related accidents on road.

2.2 Drivers Drowsiness Detection System

It is a proven fact that one of the main reasons for the traffic accident is driver's drowsiness. If we can have some technology driven mechanism with which the drivers can be warned and alarmed in the phase I or early phase II itself, before they enter the phase III of deep sleep or transition into drowsiness, a number of these unfortunate incidents could be averted. To reliably sight the drowsiness, a lot is dependent on the real time data presentation and its analysis, thereby providing timely warnings of drowsiness and alert to the drivers of the vehicle [3]. Such detection methods are often found to be limited by their failure to think about individual variations and contexts, the kind of information used etc. Drowsiness detection is often categorized into two categories intrusive and non-intrusive approaches [3]. In one of the study conducted, it was found that using a non-intrusive method such as calculating eye ratios through a camera to detect drowsiness provided the best results.

2.3 Drivers Drowsiness Detection and Monitoring System

This system represents the way of developing an associated interface to notice driver sleepiness by continuous inspection of eyes supported by Digital Image Processing (DIP) algorithms. Drooping i.e. closing one's eyes involuntarily for two to three seconds is a smart indicator of sleepiness. So, incessantly by observing at the eyes of the driver by the camera, the system will notice the sleepy-headed state of the driver and timely alerting is issued.

Main challenge in developing a powerful sleepiness detection system is to acquire correct sleepiness knowledge by picking and analyzing such symptoms and/or signs in real time. Due to its critical nature resulting in fatality these symptoms cannot be manipulated during a real time environment. The drowsiness detection system must be carefully developed and thoroughly tested for robustness.

Driver sleepiness mainly depends on:
(a) the sleep pattern of an individual
(b) the biological time &
(c) the duration of driving at a stretch [4].

The main idea behind some previous experiments is to deprive the drivers of sound sleep, or partly making them bereft of sleep, while some research institutes recruited night shift staff as their subjects; and they were completely bereft of sleep. The experiments were conducted and the results were encouraging leading to further research in the domain. Kokonozi et. al., simultaneously conducted an associate in nursing experiment within which they have monitored the staff for twenty-four hours before the experiment began, to make sure that they were fully sleep-deprived [4]. In some instances, research institutes partly diluted the themes of sleep by permitting them to sleep for fewer than half dozen hours [5] Peters et al, studied identical subjects throughout 4 consecutive days and regarded the consequences on their sleepiness level. Hence, the standard of the last sleep is a crucial criterion which influences sleepiness [6]. A CR (*circadian rhythm*) is used to check with all variations or rhythms that occur during a cycle of roughly twenty-four hours. These CR's are self-sufficing and can persist even once the organism is placed in a setting destitute of time cues. Recent stats from countries like the UK, the US, Israel indicate that a raised range of car accidents caused by driver sleepiness occurred throughout the height sleepiness periods of morning 2'o clock to 6'o clock and evening 2'o clock to 4'o clock. Throughout these time frames, the biological time shows higher likelihood of obtaining drowsy. Liu et al. biological time that the biological time produces little, however important, changes in vehicle-based measures. Research institutes have asked staff to drive between afternoon 2'o clock and evening 5'o clock to watch sleepiness by measure lid movement, ECG and EEG [5]. The period of the driving task conjointly plays a significant role in influencing sleepiness. Otamani et al, found that deprivation of sleep alone doesn't directly change the brain signals that management sleepiness, whereas the period of task features a robust influence [8][13]. Research institutes have conjointly inferred that prolonged driving in an ordinary setting stimulates sleepiness. It's been determined that the subjects will become drowsy at intervals twenty to twenty-five minutes of driving [9]. This last invention, by Philip et al., contradicts the observation created by Thiffault et al. that, during a real time setting, the period of the drive doesn't impact the performance throughout the primary 2 hours. Additionally, research institutes have found that sleepiness-related crashes are having high probability during a monotonous setting than during a stimulation setting.

The tendency of reduction in the alertness while driving, due to fatigue, resulting in drowsiness can be discovered by closely observing a gradual change in the facial features and comparing them with standard case:

i. Variations related to the gaze direction of the driver,

ii. Noticeable variation in the eyelids positioning or the size of the eyes and pupils,

iii. Increase in the rate of blinking of eyes and

iv. Observing deviations in head orientation and positioning of the person steering the vehicle

3. PROPOSED METHODOLOGY

Various steps involved in our approach as part of our solution is described and presented as under:

Step1: Find the face and eye region

In this proposed system a pre-trained frontal face detector from Dlib's library is utilized, which is based on a Histogram of Oriented Gradients and utilizes Linear Support Vector Machine (SVM) for classification [11]. Dlib's library is used to estimate the location of 70 landmarks as (x, y)- coordinates. It maps the facial structures on the face, as shown in Figure 1 which has 68 facial landmark predictor model [12][14].

Support Vector Machine (SVM) was first introduced by Boser, Guyon, and Vapnik in COLT-92. It has a collection of connected supervised learning strategies used for classification and regression of data.

SVM is a prediction tool for regression & classification, and is one of the popular methods used in different applications like hand writing analysis, facial analysis, particularly for pattern classification and mostly in regression applications.

Figure 1: 68 facial landmark predictor

From the above facial landmark predictor, the eye region points are extracted as follows:

```
# grab the indexes of the facial landmarks for the left and
# right eye, respectively
(lStart, lEnd) = face_utils.FACIAL_LANDMARKS_IDXS["left_eye"]
(rStart, rEnd) = face_utils.FACIAL_LANDMARKS_IDXS["right_eye"]
```

Figure 2: Snapshot of extracted eye region points

After starting the video stream, the elimination of lighting effects using the histogram equalization [5] which involves correcting image intensities to enhance contrast.

Step 2: Find the aspect ratio of eyes

Euclidean distances are used to calculate the Eye Aspect Ratio (EAR) using the standard points of the eye to ascertain whether eyes are opened or closed. If EAR (Eye Aspect Ratio) is greater than the threshold, then an alert is given to the driver & Message is sent to the second person.

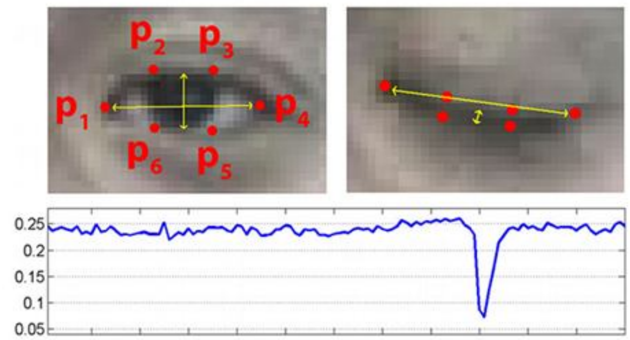

Figure 3: Visualization of eye landmarks when the eye is Opened & Closed

Using Figure 3, we get the following equation by calculating the distances between two points, giving Eye Aspect Ratio (EAR) factor:

EAR (Eye aspect ratio) =

[(distance (P2, P6) +distance (P3, P5))/ (distance (P1, P4))]

Step 3: Decision on ratio and Drowsiness

Observation, monitoring and analysis of eye movement and related characteristics help the system in arriving at decision and taking appropriate action. Some of the key considerations which goes as inputs are:

- In a normal case, on an average the eye blink is supposed to last 200-300 milliseconds & while in drowsiness it could last for 800-900 milliseconds
- time between two frames can be suitably assumed to be 100 milliseconds (varies with equipment)
- The case of Eye Blink lasting for about 300 milliseconds may be considered as normal
- If it lasts for more than 900 milliseconds, then the driver is considered to be drowsy and alert or action must be initiated

Step 4: Last step is to raise the alert & send the message

- If the eye blinking time increases beyond threshold, then the alert will be given to the driver & Message is sent to the second person already registered with the system

Following is the flow of the complete process of the drowsiness detection & monitoring system proposed and implemented by the authors. The vehicle mounted camera continuously captures the facial expression and head movement of the driver and convert the video/image format to a binary format. The binary values are compared with the saved EAR values and if found above a set threshold, alarms for drowsiness setting in and initiate the alert mechanism. If, within the threshold then no action and the process smoothly goes on.

The system is capable enough to generate a report, provide inputs for proper documentation for referring in future.

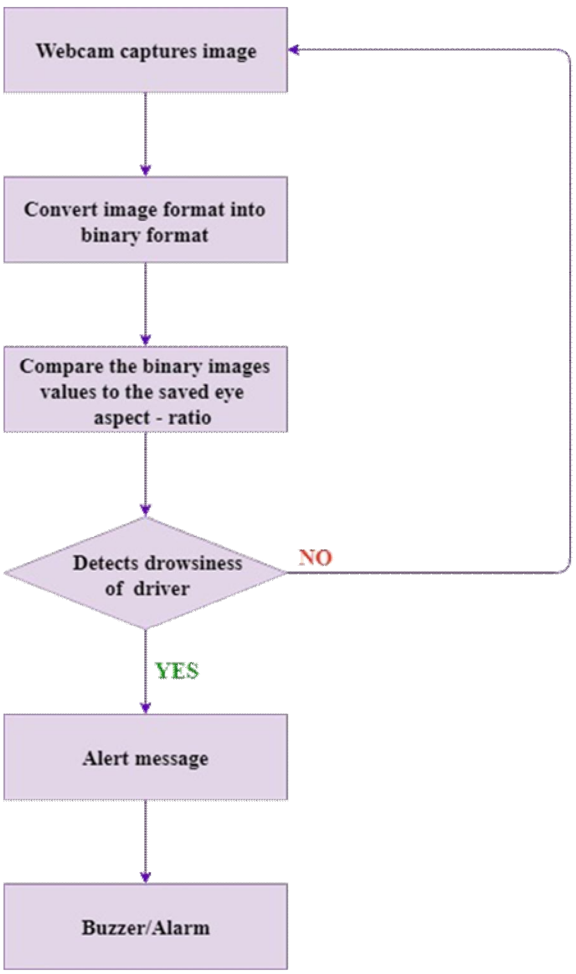

Figure 4: Flowchart to depict the steps involved in the Driver's Drowsiness Detection and Monitoring System

4. RESULTS & DISCUSSIONS

The developed system is very much robust & reliable, completely automated, user friendly, customizable and non-invasive one. Support Vector Methods technology is more powerful in comparison to the traditional ways of monitoring the person using ECG, EOG etc. [10][15]. Eye Aspect Ratio (EAR) is the key in evaluation of the drowsy conditions. If the EAR is below the threshold, the system increments the frame counter and understand normal driving. Otherwise an alarm beeps, and the driver is alerted & a message is sent to the second person who is already registered with our system.

Following are some of the snapshots of the application developed showing its working mechanisms:

The threshold value of EAR for this frame is 0.3.

Table 1: Classifier Accuracy

	Existing Solution	**Proposed Solution**
Sensitivity	0.956	0.96
Specificity	1	1
Overall Accuracy	0.958	0.96

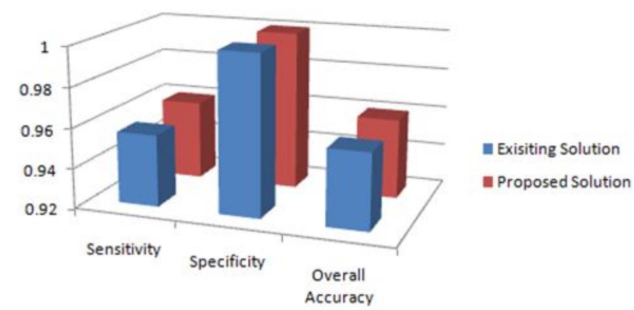

Figure 5: Comparison of existing and proposed solution

Table 2: Accuracy details for different threshold values

Threshold	**Accuracy**
0.3	0.96
0.2	0.962
0.1	0.964

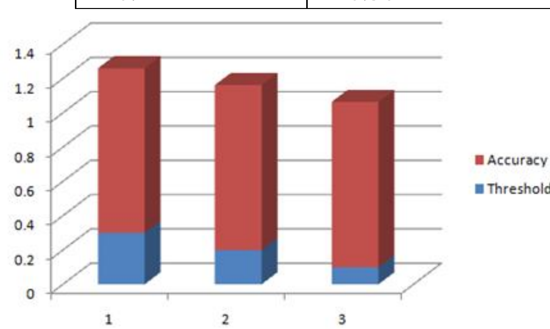

Figure 6: Accuracy and Threshold values

Table 3: Sample value for EAR in different states

State	EAR
Normal	0.3
Eye Closed	0.15

The blink duration and its comparison with the threshhold value is very much significant in this application/system. Based on the EAR calculation, our system sends an alert to the driver after detecting sleepiness symptoms and the driver can take some rest, wash face etc. before embarking on the journey again.

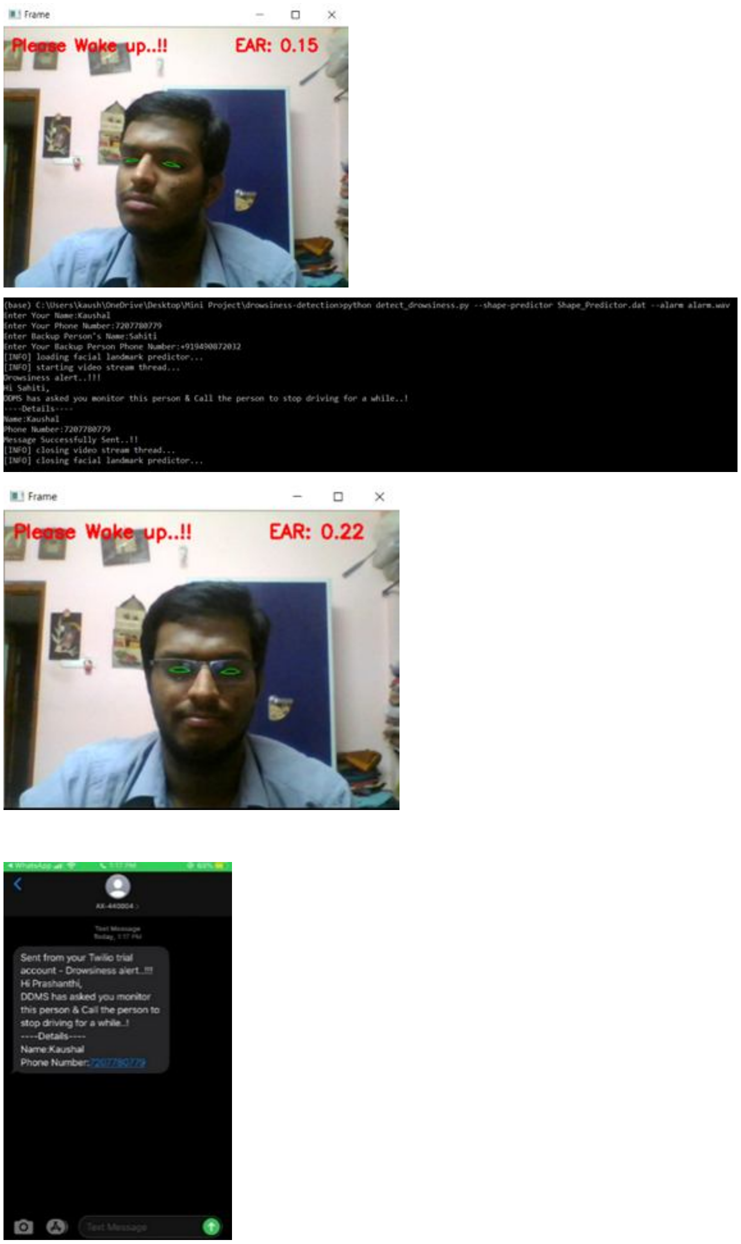

Figure 7: Drowsiness detection due to eye closing and message details

5. CONCLUSIONS AND FUTURE SCOPE

There are previous works which had been carried out by different researchers and almost of 95% accuracy was reported [1], factors considered were EAR, Mouth Length Ratio, Nose Length ratio. But the demerit reported was their limitation to be deployed in real-time environment, while our system could attain an accuracy of 96%, and is handy to install, use and implement in vehicles providing real time analytics.

To our best knowledge, if a driver is feeling drowsy, he/she may tend to ignore the warning message given to the driver. So, we have added a second person to monitor and alert the driver as soon as he gets the alert message Eye Aspect Ratio is the property which has been used in our system.

Currently, there is no such system available to the general public. Our system has performed fairly well during experimentation but some other limitations reported in the previous work are:

- if the driver turns his head or wear's sunglasses then the application won't be able to detect the face and eye points

The eye blinks in low lighting conditions as well as if the driver is wearing glasses the detection of pupils & blinking was easily detected through our system.

Future Scope

We intend to extend the above work by considering following aspects of driving and driver of the vehicle which will further improve the system making it more robust.

- Using 'k previous frames' to stabilize the landmark points
- To use the head orientation of the driver as a fatigue monitoring approach
- To observe the stress factor of the person based on the behavioral traits as captured by camera and sensors in the vehicle
- To detect the yawning frequency of the driver for making decision

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