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A New Proposal for Smartphone-Based Drowsiness Detection and Warning System for Automotive Drivers

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ABSTRACT

This paper proposes a Smartphone-based system for the detection of drowsiness in automotive drivers. The proposed system uses three-stage drowsiness detection technique. The first stage uses the percentage of eyelid closure (PERCLOS) which is obtained by capturing images with the front camera of the Smartphone with a modified eye state classification method. The system uses near-infrared lighting for illuminating the face of the driver during night driving. The second step uses the voiced to the unvoiced ratio (VUR) obtained from the speech data from the microphone, in the event PERCLOS crosses the threshold. The VUR is also compared with a threshold and if it is a value greater than that of the threshold, it moves on to the next verification stage. In the final verification stage, touch response is required within the stipulated time to declare whether the driver is drowsy or not and subsequently sound an alarm. To awake the driver, a vibrating mechanism is done and also the live GPS location is also sent to an emergency contact. We have studied eight other reference papers for the literature review. The system has three advantages over existing drowsiness detection systems. First, the three-stage verification process makes the system more reliable. The second advantage is its implementation on an Android smart-phone, which is readily available to most drivers or cab owners as compared to other general-purpose embedded platforms. The third advantage is the use of SMS service to inform the control room as well as the passenger regarding the loss of attention of the driver.

KEYWORDS: *Drowsiness, Automotive, Drivers, Warning, Detection, PERCLOS*

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I. INTRODUCTION

Long-distance driving with monotonous driving conditions often leads to drowsiness and mental fatigue in the driver. Sleep deprivation is another cause that leads to drowsiness and fatigue, which may result in road accidents and allied mishaps. Hence, it is necessary to monitor the drowsiness level of the driver and alarm him when required. Most existing solutions address the issue of estimating the drowsiness levels in drivers through a single cue. Some systems require specialized hardware, which limits their use for a general population. In many previous works, they have developed an image-based embedded plat- form for detecting drowsiness in automotive drivers solely based on eye closure rates, addressing the issues such as onboard illumination conditions, driver's head motion, etc. This method provided significant accuracy as compared to similar methods which rely exclusively on upon PERCLOS. However, the reliability from a single image based the cue may not be extremely robust. This factor motivates us to employ the findings of Dhupati et al. and integrate speech signals along with PERCLOS to increase the efficacy of the system. Moreover, if the embedded platform is a Smartphone, the system may reach a broader mass, by just installing the application. The Smartphone has added advantages of using cellular data and networks for communication, thus enabling the system to send warning messages to control rooms. This communication feature will help cab owners to maintain a record of the drowsiness levels of their drivers and take necessary actions drivers. Such an implementation may assist every single automotive vehicle as a preventive tool for accidents occurring due to drowsiness or fatigue.

II. LITERATURE REVIEW

A prototype of the PERCLOS camera for measuring eye closure in a heavy truck environment is discussed in the paper "A Drowsy Driver Detection System For Heavy Vehicle" [1], This eye tracking system was designed using CCD (charge coupled device) imaging technology along with a dedicated PC/104 with PCI Bus computer platform. The PERCLOS camera exploits the basic property of human eye in which the retina reflects different amounts of infra-red light at different frequencies. The computation is basically done with the help of the System's algorithm. Prior to calling any program routines, the system must be initialized. It requires two equally illuminated images of the driver's face which is captured by the two CCD cameras placed perpendicular to each other. Bright-Spot Segregation routine run to distinguish eye from noise once isolated, the retinal image sizes are measured, and the results are used to calculate PERCLOS Calculated height of each observation in a data file is stored on a hard disk. Some of the advantages of the above mentioned idea are that it can run in real time without operator intervention. Also the PERCLOS camera was able to eliminate many of these spurious reflections through the subtraction process. The main drawbacks of the mentioned paper are the increased amount of infra-red light going to the eye causes damage to the eye after prolonged exposure. Also there were problems experienced in Timing control and synchronization with the 2 CCD cameras.

Localization of human faces in digital images is a fundamental step in the process of face recognition. The paper "Robust Face Detection Using the Hausdorff Distance" [2] presents a shape comparison approach to achieve fast, accurate face detection that is robust to changes in illumination and background. The proposed method in this paper is edge-based and works on grayscale still images. Hausdorff distance is used as a similarity measure between a general face model and possible instances of the object within the image. In this paper describes an efficient implementation, making this approach suitable for real-time applications. A two-step process that allows both coarse detection and exact localization of faces presented. Experiments were performed on a large test set and rated with a new validation measurement. Some advantages are the better localization results show that the system is ro- bust against different background conditions and changing illumination. Runtime behavior of this method allows the use in real-time video applications. The main drawback is the restrictions of the detection of only frontal views and single faces, on automatic model creation and on transformation parameter optimization.

The paper "The Study of Driver Fatigue Monitor Algorithm Combined PERCLOS and AECS" [3] discusses the idea of combining PERCLOS and AECS to introduce an algorithm to detect the driver fatigue. The algorithm, based on color image skin color segment can directly transform the RGB form image to the gradation image by the skin color segmentation, and then the eyes are detected. Then they identify eye's condition through the judgment of eye area. PERCLOS and AECS algorithms are combined to detect the driver's fatigue. It is emphasized that the color segmentation and the removal of the regional border connectivity are used to locate the eye. This method can't be influenced by complex background, and it is suitable for faces of different skin color and guise. The goal of eye detection and tracking is for subsequent eyelid movement monitoring, gaze de- termination, face orientation estimation and facial expression analysis. A robust, accurate, and real-time eye tracker is therefore crucial. This method records the times of eyes were open and eyes were close, and the beginning and the ending time, and then it computes the value of PERCLOS. If the value is more than 40% and the time that eyes are in the closed state maintains more than three seconds, this algorithm will conclude that the driver is in the state of doze and this situation will be detected as fatigue driving.

The paper "Eye State Classification Based on Multi-feature fusion" [4] was proposed by Wenhui Dong, Peishu Qu Department of Physics, Dezhou University, Dezhou back in 2009. The State of the eye, open or closed contains a lot of information about the expressions and can be used in many Fields, such as driver fatigue detection, face expression analysis etc. After the characteristics of the infrared image of the eye was studied, the paper fuses four features together using fuzzy fusion to judge the eye state .This method can overcome the drawbacks suffered in the single feature classification methods and realize the complementary of information. Also, it can obtain a higher correct rate of classification. It was decided that the extraction of the features are iris area, eye height, eye area and eyelids curvature's) Eye Area Extraction: After obtaining the infrared image of the eye, we see that the gray-level change is obvious in the image, so gray-scale distribution can be used to choose a right threshold to binarization and 150 is selected as the threshold. ii) Eyelid Curvature Extraction: The up-eyelid also can be extracted from the binarization image.iii) Eye height Extraction: This is done by scanning from the middle of the up-eyelid down to the end pixel which is not zero and calculating the distance between the two pixels. Iris Area Extraction: When the eye is completely open, the iris is similar to a circular. Multiplying the vertical distance and horizontal distance we obtain the area called the iris area. BP Network Establishment: After the four parameters exaction, the eye area and the eyelid-curvature are selected as a vector, the eye height and the iris area are selected as a vector.

An idea which uses voice response analysis of human subjects for assessing their level of fatigue or drowsiness were proposed in the paper ”A Novel Drowsiness Detection Scheme Based On Speech Analysis With Validation Using Simultaneous EEG Recordings” [5]. The results are simultaneously validated through the Electroencephalography (EEG) based measurements. A 36 hour long experiment was done where the subjects are asked to repeat a particular sentence at different stages. The response time is analyzed for computing various parameters such as voiced duration, unvoiced duration, and the response time. They have used Mel Frequency-Cepstral-Coefficients (MFCC) as the features for the silence, voiced and unvoiced parts of speech. They have segregated these parts using a Gaussian Mixture Model (GMM) classifier. They have used short time analysis of speech because the acoustic properties of the speech changes continuously during an utterance. The unvoiced and voiced speech has been extracted with the help of MFCC features followed by a GMM classifier. The ratio of voiced to unvoiced speech has been calculated and was found out that the ratio decreases during the successive stages of the experiment when the driver starts to feel drowsy. This analysis can be used to make conclusions that the vocal tract offers more constriction to airflow from the lungs as the level of fatigue increases for which the unvoiced speech duration gets affected. The response time was also observed to change with fatigue but it was found to be unsuitable for fatigue detection because of large deviation.

The paper ”A PERCLOS-based Driver Fatigue Recognition Application for Smart Vehicle Space” [6], they have considered PERCLOS to evaluate driving fatigue status by measuring the proportion of eyes closed in a certain period of time or interval of time and the continued closure time. PERCLOS is the percentage of eyelid closure over the pupil over time and reacts slow eyelid closures rather than blinks. A PERCLOS drowsiness metric was established in a 1994 driving simulator study as the proportion of time in a minute that the eyes are at least 80 percent closed. In which PERCLOS = frames of the eyes closed / (frames of eyes open + frames of eyes closed) × 100 percentage. Smart vehicle space software platform uses a smart space oriented context aware system framework-S2CAS :The first layer, called the original context in- formation perception layer, is responsible for collecting all kinds of smart vehicle space dynamic context, such as latitude and longitude data, car bus data, facial features data, voice data, various sensor data and electronic maps, the user information database, configuration files, and virtual context the second layer, smart vehicle space SCUDW are, is responsible for shielding the underlying differences of various devices and the structure of sensors, analyzing and reasoning the data from the original context information perception layer, managing the equipment and objects, integrating various functional modules, providing for the application run time environment; the third layer is applications and services layer, which contains human-computer interaction interface, to provide users with a variety of car-based applications and services, such as safety tips, navigation tips, information services, entertainment services, in-car environment control and so on.

The paper ”Analysis of Training Parameters for Classifiers Based on Haar-like Features to Detect Human Faces” [7], analyzes the performance of Haar-like feature based classifier for detection of face with fewer features. In lower dimensional feature space representation of the image might reduce the computational burden compromising the accuracy in detection of faces with varying orientations. In this work they train the classifier with positive instances of different orientations under such feature constraint. Training parameters like maximum deviation and maximum angle are varied to form different classifiers. In experimental results show optimum values of the design parameters can produce good performance of the classifier to detect tilted human faces. Haar-like features are generally used to detect and recognize objects. A Haar-like feature considers the rectangular regions at a specific location within a detection window. Then the intensities of pixels in these regions are summed. Finally calculates the difference between these regions. Some advantages are the classifier detects the frontal faces with high accuracy and optimum values of the design parameters can train a classifier to provide good performance for detection frontal and tilted human faces. The main drawbacks are, best performance achieved only at moderate values of the maximum deviation and maximum angle and cannot choose the maximum angle and maximum deviation arbitrarily high or low.

Another method is proposed in the paper, ”Driver Alertness Monitoring Using Fusion of Facial Features and Bio-Signals” [8]. It measures driver’s tiredness using two distinct methods: eye movement monitoring and bio-signal processing. A monitoring system is designed in Android-based Smartphone where it receives sensory data via wireless sensor network and further processes the data to indicate the current driving aptitude of the driver. It is critical that several sensors are integrated and synchronized for a more realistic evaluation of the driver behavior. The sensors applied include a video sensor to capture the driver image and a bio-signal sensor to gather the driver photoplethysmograph (PPG) signal.PPG sensors use a light-based technology to sense the rate of blood flow as controlled by the heart’s pumping action.PPG is not a complicated nor expensive optical measurement method that is often used for heart rate monitoring purposes. PPG is a non-invasive technology that uses a light source and a photo detector at the surface of skin to measure the volumetric variations of blood circulation. Relaxation, extreme fatigue and drowsiness episodes can be measured non-invasively from the Pulse Rate Variability (PRV) signal obtained from photoplethysmography signal (PPG).

A dynamic Bayesian network paradigm is applied for fatigue analysis. DBN paradigm is a probabilistic graphical model which uses different mathematical methods to model an object based on the given input data. The foremost reason of adapting DBN is that its ability to integrate distinct categories of parameters even the extraction methods, measurement techniques, and etc. of those parameters are different. The proposed system detects biological variation with very high accuracy .Video and biological sensors are integrated for a more realistic and accurate evaluation of the driver behavior. PPG works best in optimum lighting conditions; bad lighting may affect the accuracy of the pulse oxymeter, since it works on the amount of light reflected from skin. The PPG measures vary if the subject has any heart related or other such illness since, when the PRV of the subject is calculated, if the subject has heart problems, the pulse will very irrespective of his/her drowsiness levels,

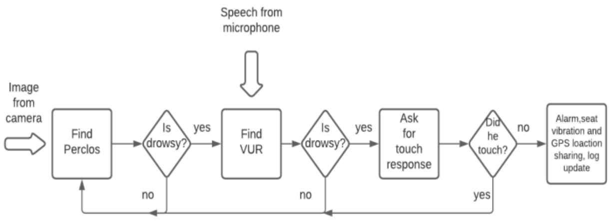
The paper ”Monitoring Driver’s Drowsiness Status at Night Based on Computer Vision” [9] basically deals with Drivers drowsiness and fatigue decreases the vehicle management skills of a driver. The operator driving vehicle in night has become a significant downside today. Driver in a drowsiness state is the one among the important reason of increasing amount of road accidents and death. Hence the drowsiness detection of driver is considering as most active research field. Many ways are created recently to detect the drowsiness of driver. Existing methods can be classified in three categories based on physiological measures, performance measures of vehicles and ocular measures. Few ways are intrusive and distract the driver from comfortable driving. Some of the methods need expensive sensors for information handling. Therefore, a low cost, real time system to detect the driver’s drowsiness is developed in this paper. In this proposed system, real time video of driver records using a digital camera. Using some image processing techniques, face of the driver is detected in each frame of video. Facial landmarks points on the driver’s face is localized using one shape predictor and calculating eye aspect ratio, mouth opening ratio, yawning frequency subsequently. Drowsiness is detected based on the values of these parameters. Adaptive thresholding method is used to set the thresholds. Machine learning algorithms were also implemented in an offline manner. Proposed system tested on the Face Dataset and also tested in real-time. The experimental results shows that the system is accurate and robust.

III. PROPOSED METHODOLOGY

This proposal use three-stage drowsiness detection. The first stage uses the percentage of eyelid closure (PERCLOS) obtained through images captured by the front camera with a modified eye state classification method. The system uses near infrared lighting for illuminating the face of the driver during night driving. The second step uses the voiced to the unvoiced ratio obtained from the speech data from the microphone, in the event PERCLOS crosses the threshold. A final verification stage is used as a touch response within a stipulated time to declare the driver as drowsy and subsequently sound an alarm. The device maintains a log file of the periodic events of the metrics along with the corresponding GPS coordinates. PERCLOS is a tiredness metric, based on eye close and open rates. It has been proved as a significant marker of drowsiness. PERCLOS can be defined as the approx proportion of time in which the eyelids are at least 80% closed over the pupil. A value of PERCLOS above the threshold(80%) indicates higher drowsiness level and vice versa. Voiced and unvoiced proportion is carried out with the help of a support vector machine (SVM) with the Mel frequency cepstral coefficients (MFCC) as its features. MFCC represents the short-term power spectrum of the speech signal comprises of the voiced and unvoiced bits.

Support Vector Machines (SVMs) are trained or supervised learning methods which helps for regression and classification tasks that is originated from statistical or mathematical learning theory. As a classification method, SVM is a general or global classification model that develops no overlapping divisions or partitions and usually employs all the attributes. Support Vector Machines (SVMs) are trained or supervised learning methods which helps for regression and classification tasks that is originated from statistical or mathematical learning theory. As a classification method, SVM is a general or global classification model that develops non-overlapping divisions or partitions and usually employs all the attributes.

Fig 1 Flowchart of Proposed System



The PERCLOS value of a subject is calculated as

P= Ec / (Eo + Ec) * 100 (1)

Here, Ec and Eo shows the counts of closed and open eyes for a predefined interval. A higher value of P shows there is higher drowsiness level and vice versa. The steps in the calculation consists of calculating the PERCLOS from an image batch involves the face detection followed by eye localization and eye state classification. Real-life driving have its own challenges, where both the illumination and the head angle or pose of the subject or driver is a problem to be considered. We try to solve this problem by preprocessing the images by geometric and photometric correction methods. Photometric Correction: Let the input image be I of size N × M. The image is subdivided into blocks of size N h × M w. We hence obtain a total number of h × w boxes, obtained as:

h = N / N h (2)

This process elevates the local contrast and increases the details in the image. What so ever, there are some kind of blocking constraints at the boundaries of the corrected sub images, when concatenated to form. A smoothing process[10] by a 5×5 Gaussian filter solves this particular problem.

Geometric Correction: This correction is done in the event where the driver's face has a tilt or deviation of more than +30 degrees or -30 degrees from the vertical straight face. An affine rotation of the pixels of the pre-enhanced image helps to develop a new image which geometrically sets the angle of the face in an upright position.

Face and Eye Detection: It is clear that for the accurate or exact estimation of PERCLOS, fast and correct location of the eyes are necessary. For localizing or locking the eyes, we first locate the face region[11] from the pre-enhanced image. This step not only reduces the search space for eye location but also reduces the false alarms in locating the eye or in the detection stage. We use a classifier based on Haar-like features for face which are trained with optimal parameters. From the detected face region, we search for the eyes in the upper half of the face region. We have employed a Haar classifier trained with eye images. Two classifiers are trained - one for visible image during daytime driving and the other for NIR images during nighttime driving.

Eye State Classification: For the accurate estimation of PERCLOS, the localized eye region needs to be accurately classified into opened or closed states. A new set of features based on the fusion of information of edges and their orientations is proposed here.

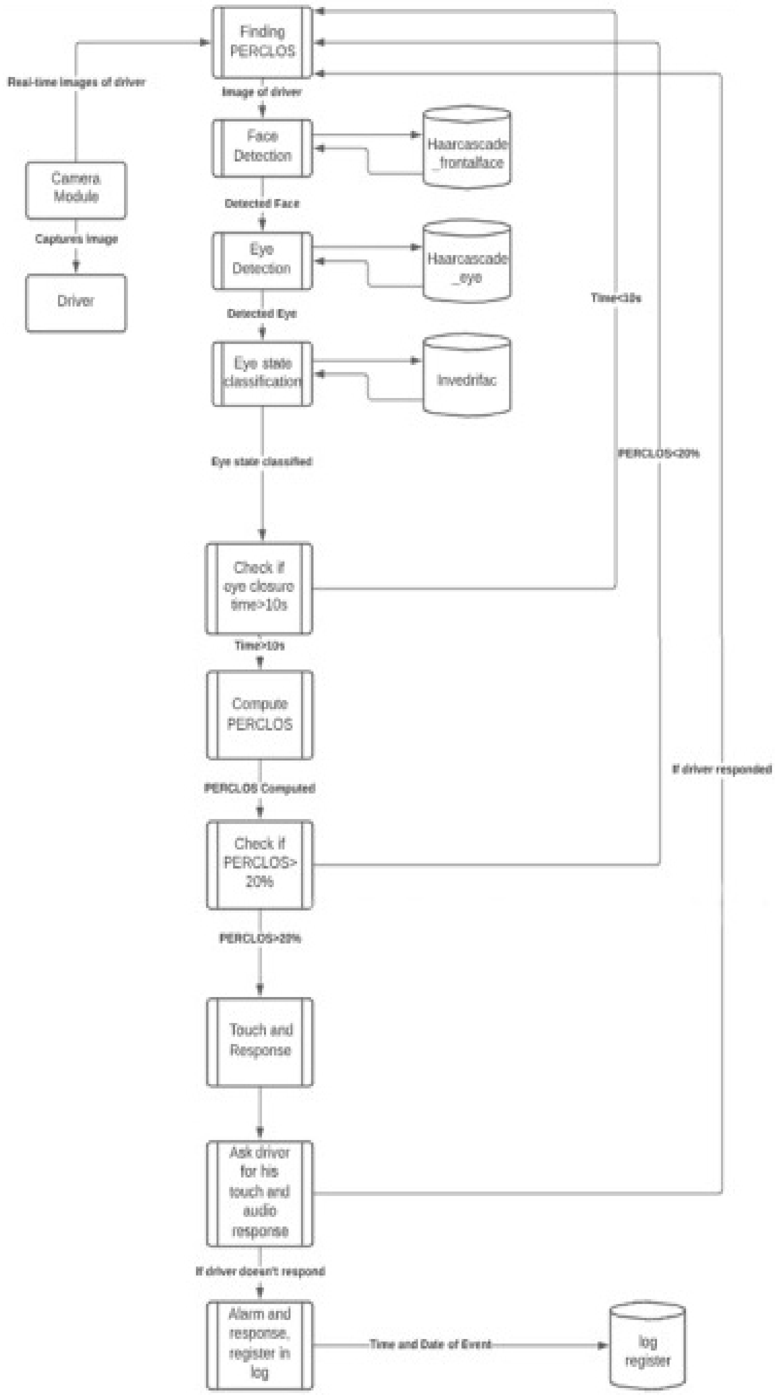
A. Gradient Image Computation: We first obtain sub images E i, j of size 8 × 8 from the eye image E with a 50 % overlap in both the directions. Each sub image E i, j is passed through the Sobel operators and gradient images are obtained.
B. Orientation Computation: The edge-maps are exposed to gradient operation to find the oriented gradients.
C. Feature Computation: The selected features perform better than other competing features such as edge orientation histograms, scale-invariant feature transform descriptors, because they use overlapping local contrast normalization to obtain improved accuracy[12].
D. Classification: We train a linear SVM with 1200 images of which 700 are open and 500 are closed eye images taken from the database created using normal and NIR illumination.
E. PERCLOS Computation: Once the eyes are classified as open or closed, the algorithm computes the PERCLOS value using over a sliding time window of 10 second duration.

A fusion of additional cues such as speech signals can make the drowsiness detection sys- tem more reliable. The voiced unvoiced ratio (VUR) of speech signals has been validated, as an indicator of drowsiness. The inbuilt microphone of the Smartphone to capture speech signals sampled at 20 kHz, since speech information is up to about 7.5 kHz is used here. This speech data is processed frame-wise. The vocal fold vibrations may be assumed periodic if the signal is of short duration (10-30ms). For this reason, the speech data is processed in small frames of size 10-30 ms.

Singular Value Decomposition (SVD) is performed frame wise to remove noise and redundant information. Voiced speech is produced by the vibrations of vocal cords whereas unvoiced sounds are due to the turbulence of air in vocal tract (mouth, tongue, velum, etc.).Unvoiced speech has lower energy and higher zero crossing rates as compared to the voiced speech. Voiced and unvoiced classification is carried out using a support vector machine (SVM) with the Mel frequency cepstral coefficients (MFCC) as features. MFCC represents the short term power spectrum of the speech signal. Once the MFCCs are obtained, the SVM returns the voiced speech v s (n) and unvoiced speech u s (n)f lengths N v and N u respectively. The VUR is finally obtained as the ratio of the energies.

The third and final verification stage of the framework is the touch-based reaction. In this stage, the driver is asked to touch the Smartphone screen within a stipulated time of 10 second after a voice instruction asks to do so. This stage is invoked when both the voice and vision based classification methods predict the driver to be drowsy. In the event the driver fails to respond within 10s, the final decision is drowsy, and the alarming sound is generated through the speakers. Along with this, an SMS along with the GPS location of the driver is sent to an emergency number which was obtained at the start of the ride. A vibration hardware is worn around the hand like a band which vibrates, awaking the driver. The event is also marked in the log file stored in the internal memory of the Smartphone.

Fig 2 Detailed Procedure of Proposed System



IV. CONCLUSION

We have proposed a Smartphone-based drowsiness detection solution for automotive drivers, which undergoes a three-stage verification process to detect the drowsiness in drivers. The measures are PERCLOS, VUR, and a reaction test response of the driver on the smartphone screen along with an alert system which produces a beep sound, vibrates the driver arm by a hardware worn by the driver thereby alerting the driver. Each stage is activated based on the decision of the preceding stage. The system maintains a register log which marks the events when the driver was found to be drowsy based on the PERCLOS, VUR and touch response. The application has an option to upload the log file to a cloud server to maintain a record. This option will be useful to cab service providers, who can keep their records based on driver performance. We have tested the sub-operations such as the eye state classification, PERCLOS, and VUR-based drowsiness state classification individually as well as with the combined measures and cross-correlated the estimated cues against standard cues. The device may be suitably modified to monitor the loss of attention of any person engaged in a critical safety operation. With improvements in the acquisition frame-rates of the front camera, fast ocular motions such as eye movements may be captured, which can provide earlier indications of the onset of fatigue. An extension of this work may be tracking the road conditions using the primary camera along with the drivers drowsiness level in parallel. However, such an implementation would require a lot of multi-threading operations.

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