Journal of Physics: Conference Series **2325** (2022) 012057 doi:10.1088/1742-6596/2325/1/012057

Driver Drowsiness Detection and MonitoringSystem using Machine Learning

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Abstract: In the present world, lots of road accidents take place due to the lack of attention and alertness of driver. This is termed as driver drowsiness. This leads to a lot of unfortunate situations causing adverse damage to human lives. The main goal of this research is the detection of driver drowsiness and an appropriateresponse to the detection. There are many methods which are based on the motion of the vehicle or based on the driver's behavior. One of the methods is the physiological method which helps in distracting the driver from drowsiness and making him alert. And few methods require expensive sensors and deals with a lot of data. Therefore, this paper develops a system for detecting drowsiness in realtime with proper procedure and accuracy which is acceptable. In this system, the driver's facial expressions are captured and recorded using a webcam. Every movement in each frame is detected using few techniques of image processing. The Eye Aspect Ratio, Mouth Opening Ratio, and Nose Length Ratio are calculated using the landmark points on the face. The calculated values are compared to the threshold values developed by the system and the difference in value leads to thedetection. At the same time, the machine learning algorithms are also implemented in offline manner. Based on the classification,the system has successfully achieved 95.58% of sensitivity and100% of specificity using Support Vector Machine. This modelsystem is compatible with all kinds of vehicles.

1. Introduction

Many road accidents which lead to death are because of drowsiness while driving. Drivers who drive long hours like truck drivers, bus drivers are likely to experience this problem. It is highly risky to drive with lack of sleep and driving for long hours will be more tiresome. Due to the drowsiness of thedriver causes very dangerous consequences, it is estimatedthat 70,000 to 80,000 injures & crashes happen worldwide in a year. Even deaths have reached 1000-2000every year. There are many unofficial deaths which are not confirmed by drivers that it was due to their drowsiness. This takes lives of many innocent people. It is a nightmare for alot of people who travel across world. It is very important to identify the driver drowsiness and alert the driverto prevent crash.

The goal of this research is the detection of the indication of this fatigue of the driver. The acquisition system, processing system and warning system are the three blocks that are present in the detection system. The video of the driver's front face is captured by the acquisition system and it is transferred to the next stage i.e., processing block. The detection is processed online and if drowsiness of driver is detected, then the warning systemgives a warning or alarm.

The methods to detect the drowsiness of the drive may be done using intrusive or nonintrusive method i.e., with and without the use of sensors connected to the driver. The cost of the system depends on the sensors used in the system. Addition of more parameters can increase the accuracy of the system to some extent. The motivation for the development of cost effective, and real-time driver drowsiness system with acceptable accuracy are the motivational factors of this work. Hence, the proposed system detects the fatigue of the driver from the facial images, and image processing technology and machine learning method are used to achieve a cost effective and portable system.

2. Methodology

The Machine Learning is an approach of getting the effect automatically. ML is the concept which is linked with many complex and advanced Algorithms, and it can be easily used with the Python programming language. The two librarieswhich contains the machine learning algorithms are:

1. scikit-learn Library
2. Pandas Library

The SVM algorithm used in this project is present in the library scikit- learn. It represents humans as machines, which is the Machine Learning. In order to gain high accuracy and high efficiency, it is necessary to implement Machine Learning algorithms.

2.1. Machine Learning with Python:

The Python properties are Platform Independence, Object Oriented and Robust Language. It has the machine learning algorithms in pandas and scikit-learn library and is an Open-source language.

2.2. Libraries:

1. NumPy: NumPy stands for Numerical Python. It usually includes all types of mathematical operations in the code. It performs linear algebra as well as matrices.

2. Pandas: Pandas are efficient libraries in Python Languages. These are imported and used for managing the datasets. In orderto train the machine using a dataset, dataset should be stored in a variable. This can be done using Pandas Library.

3. Seaborn: Seaborn is used for styling the pictorial representation such as bar graphs, curves etc. By using this library, the difference between the attributes is determined with the colors i.e., each attribute is distinguished with different color.

4. Sklearn: Sklearn is the most used library for implementing machine learning techniques. It is an open and free software

machine learning library. It is also used for performing Regression, Clustering, and Statistical Modeling. Everyone can access and use it, and sklearn is reusable in various contexts. Sklearn has many Machine Learning algorithms, and this library is also called as inbuilt Machine Learning technique. Sklearn has Logistic Regression, RF algorithm, feature extraction, classification report, and confusion matrix. These packages are inbuilt such that these can be accessed directly and can be used for the classification and prediction projects.

3. Existing Approach

There are three types of general methods to detect driver drowsiness; they are, vehicle-based, behavior-based and physiological-based methods. The steering wheel movement, the accelerator of vehicle or pattern of vehicle brakes, vehicle's speed, and deviation in position of lane are monitored continuously in the method which is based on vehicle [5].If there is any deviation in the values detected, it is considered as driver drowsiness. The sensors are not connected to the driver and this measurement is nonintrusive.

Visual behavior like blinking of eye, closing of eye, yawning, bending of head etc. are examined for drowsiness detection in behavioral based method [1]. A simple camera is used to take images to be sent as input to SVM algorithm to identify the above features and are called nonintrusive measurement. Monitoring the physiological signals like EOG, ECG, the heartbeat, EEG, pulse rate etc. [2,3] helps in detecting driver drowsiness based on physiological method and they are intrusive measurement due to the directconnection of sensors to the driver.

The current detection of the drowsiness methods are mainly based on the machine learning algorithms.

4. Proposed Approach

Almost all drivers have experienced this drowsiness problem while driving [7]. Youngsters and professional drivers are mostly affected by this drowsy driving because of continuous hours of driving without any rest. In many cities, auto drivers and cab drivers drive continuously overtime sometimes to complete their targets or at times to get bonus profit. Many of the poor workers in order to meet their daily expenses and for the sake of their loved families tend to work in night shifts for long time, this can be one of the main reasons for accidentstaking place because of drowsy driving.

Therefore, a driver drowsiness monitoring system has been developed in this paper. The block diagram of the proposed method for drowsiness monitoring is shown in figure 1.

A webcam has been used to record the video of the driver. The webcam is arranged in such a way that it captures the front facial image of the driver [8]. Once the video capturing is done, the recorded frames are then pulled out to get the 2-Dimensional images [9]. The object (Face) in the frames is detected by HOG and SVM algorithm.

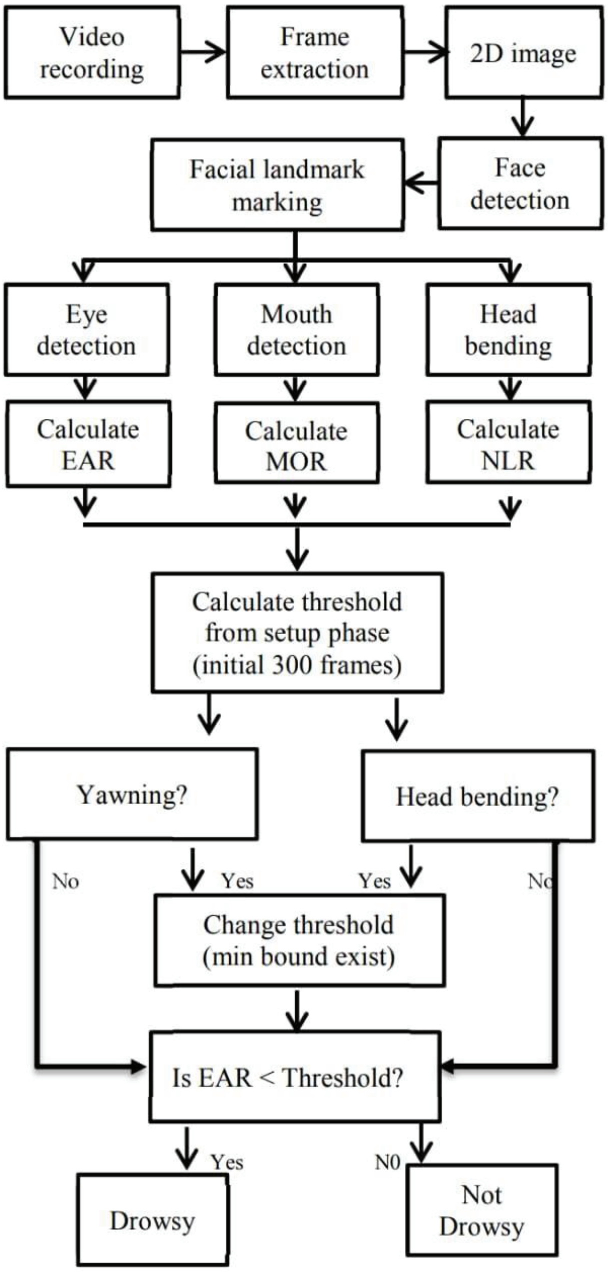

Fig.1 The block diagram of drowsiness detection system

5. Implementation

5.1 Acquiring Data:

At first, the video is captured and recorded using a laptop webcam and then the frames are released and proposed in a laptop. Then after the completion of extraction of frames, the picture implementation techniques are proposed on the 2-dimensional picture of the recorded video. Now, the required driver information is produced. The volunteers are asked to focus on the laptop webcam and perform activities like continual eye blinking & closing, mouth yawning, and head bending. And the webcam is adjusted to capture the video for 20 to 30 min.

5.2 Face Identification:

The driver's face is identified first after the frames have been extracted. In this paper, HOG & SVM algorithms [10] are used for face extraction. In this detection, only positive examples of the stable window size are taken for photographs and histogram of oriented gradients (HOG) descriptors are calculated on them. Following that, the negative examples of same size are considered for HOG descriptors and then results are evaluated. Typically, the count of negative examples is more than positive examples. Then after getting the characteristics of both the groups, a direct SVM algorithm is used for classifying the required task. To get more detection and better accuracy for SVM algorithm, strong negatives are used. In this detection, after the guidance, the SVM classifier is investigated on labeled data and the incorrect positive example characteristic values are reused for guidance purpose. To test the picture, the window used for positive examples are rendered over the image and then the required result or output will be classified for each window location. Then based on the results obtained and considering the various sample results, the higher value samples are considered for drowsiness identification and the boundary outline is drawn on the face. This minimum elimination steps will reduce the overlapping and redundant bounding in the bounding box.

5.3 Locating Face Points:

After the detection of faces, the further step is to locate the points on the human face like eyes, mouth, nose etc. Then the photograph that used for face detection has to be normalized to minimize the distance factor between camera and the driver. Therefore, the face photograph is resized with the width of 500 pixels and converted into gray scale pictures. Then normalization is done for regression trees [11]. And it will be approximate the positions of location points on the face from pixel intensities. In this process, the square error loss is reduced by using gradient boost learning. Different priors are used to discover various structures. By considering this procedure, the location of the boundaries of eyes, mouth and nose are noted and shown in Table I. Then the location points on face are marked and shown in fig.2. The red points on the figure are used for further identification.

Parts	**Landmark Points**
Mouth	[13-24]
Right eye	[1-6]
Left eye	[7-12]
Nose	[25-28]

Table I: The location points on face

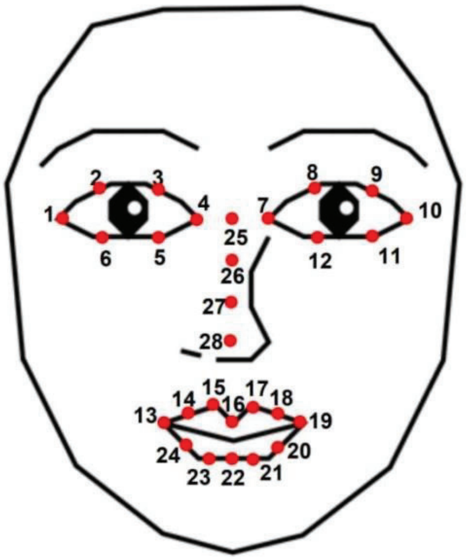

Fig.2 The landmark points on face

5.4 Feature Extraction:

After marking the points on face, the drowsiness features are calculated as given below.

Eye Aspect Ratio (EAR): From the boundary points on the eyes,the EAR is evaluated as inverse ratio of width of eyes to the heightof eyes. The mathematical formula for EAR is given as,

$$EAR = \frac{(p_2 - p_6) + (p_3 - p_5)}{2(p_4 - p_1)}$$

where i is the point marked as i in facial landmarking (i − j) gives thedistance between the points i and j. When the eyes are open EARis max and when the eyes are closed, the EAR is approximated to zero. So, the decreasing value of EAR indicates the closing of eyes andidentifies the drowsy behavior of the driver.

Mouth Opening Ratio (MOR): Mouth Opening Ratio is definedas the identification of yawning of the driver and ultimately drowsiness detection is done. The mathematical formula for calculating the MOR is given as,

$$MOR = \frac{(p_{15} - p_{23}) + (p_{16} - p_{22}) + (p_{17} - p_{21})}{3(p_{19} - p_{13})}$$

The MOR ratio is maximum when the mouth of driver is open and if it remains same for some time, then yawning condition is indicated. And if it decreases towards zero, then the condition is considered as normal, and not yawning.

Nose Length Ratio (NLR): When the head of the driver is down along withvertical axis, then by using the bending angle of head the drowsiness alert is identified. The focal plane of the webcam is directly proportional to head bending, and by using this head bending is calculated.

Normally, the nose makes an acute angle with the webcam. The acute angle increases when head moves upward and vice versa. Therefore, the nose length ratio is given as nose length to average length of nose, which also measures the head bending. The mathematical formula for NLR is given as,

$$NLR = \frac{nose\ length\ (p_{28} - p_{25})}{average\ nose\ length}$$

The facial points for nose length ratio and head bending are shown in figure.2.

5.5 Classification:

After obtaining the values of eyes, mouth and nose, the next step is to identify the drowsiness from the SVM frames. The flexible value of threshold is required for the drowsiness. Then, algorithms like SVM are used for the classification of the information.

For obtaining the threshold values for eyes, mouth and nose the initial condition of the driver is assumed to be in normal state. This step is known as setup phase. The EAR for nearly 100 to 300 frames will be recorded, and from this an average of150 to 200 higher values are recognized as strong threshold valuesfor EAR. The values which are high i.e., in which eyes are not closedis considered. If threshold is more than the tested value, then it is identified as eyes closed. For every person, the size of eye will be different; so, this makes the impact to decrease the setup for personto person. For computing MOR values, the threshold value of frames is calculated based on the condition that the mouth is not open. If the threshold is less than the test value i.e., when the mouth is open, the yawning is identified. Using the head bending feature, the angle between access and head can be determined in terms of nose length ratio. NLR values range from 0.8 to 1 in normal condition of headand varies with head bending up and down. The average of the NLR is measured as mean of lengths of nose in the setup assumingthat head is not bend. After obtaining the threshold values, it is tested. Then, if at least one of the eyes, mouth and nose identifiers are not satisfied, then drowsiness alert is indicated. In practical, for example out of 75 frames at least 70 frames satisfy drowsiness conditions for one or more features, then the overall system is identified as drowsiness detection and the driver is alerted with the alarm sound.

To overcome the thresholding problem, a single value of thresholdis considered, and this threshold value depend on EAR. Toobtain the average value of EAR, 150 higher EAR values from 300 frames are considered. If the threshold value is more than EAR value, then the driver is at danger. By considering yawn andhead bending, this EAR threshold will be increased, and it isdispersed into more frames. The yawning and head bending frames are combined to get flexible value of threshold. If EAR value is more than obtained threshold value, thenthat condition is treated as drowsiness, and this indicates to alert. In head bending situation, if the head is down, then theframes are considered for a drowsiness alert. Table II shows the calculated parameters.

The machine learning algorithms and the threshold factors are used for the identification of driver's drowsiness, from the values obtained from EAR, MOR, and NLR. Earlier, these features were used for the analysis of classification from feature space to individual. However, here it is used for the principal component analysis [12].

Table II. Calculated parameter values of threshold

EAR from setup phase (average of 150 maximum values out of 300 frames)	0.34
Threshold = EAR - offset	0.34 - .045 = 0.295
At Yawning, (MOR > 0.6)	Threshold = Threshold +0.002 *Max bound exist
At Head Bending, (NLR < 0.7 OR NLR > 1.2)	Threshold = Threshold +0.001 *Max bound exist

After converting the values obtained from threshold, whether the features are significant for classes or not is tested. If three factors give five percent significance, this classification based on Bayesian Classifier and SVM algorithm is used [12].

6. Results And Discussion:

The webcam of the laptop is turned ON and the face of the driver is recorded and captured. The captured video is transferredto the processing block to identify the drowsiness detection. If mishap is detected, then alarm will buzz a sound to alertthe driver. The initial state of driver condition is given in Fig. 3. For this frame the values are given as,

EAR= 0.350, MOR= 0.341, NLR= 1.030

Table III: Sample values of distinct parameters & states

State	EAR	MOR	NLR
Normal	0.35	0.34	1.003
Yawning	0.22	0.77	0.76
Eye Closed	0.15	0.419	0.876
Head Bending	0.15	0.577	0.66

The system can also detect the driver's drowsiness along withspectacles as shown in Fig. 5.

The algorithms are used for the testing on the INVEDRIFAC dataset [13].

7. Conclusion

This paper has designed a system for the identification of drowsiness by implementing the machine learning algorithms andvisual behavior features like Eye Aspect Ratio, Mouth Opening Ratio and Nose Length Ratio. These features are calculated from the threshold values by recording the video using a webcam on laptop. This flexible technique is used for identifying the threshold value of drowsiness detection. The developed system works perfectly with the given data. Later, the values of threshold are stored and the algorithms of machine learning arecused. Here, algorithms like SVM and Bayesian classifier are used, that performs the perception of SVM which is 0.569. SVM algorithm gives more accuracy and the system developed using SVM algorithm gives ideal output. In future, the proposed model can be implemented in real life as hardware in car and bus to validate the developed system.

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