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Review on Drowsiness Detection for Automotive Drivers in Real-Time

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Abstract

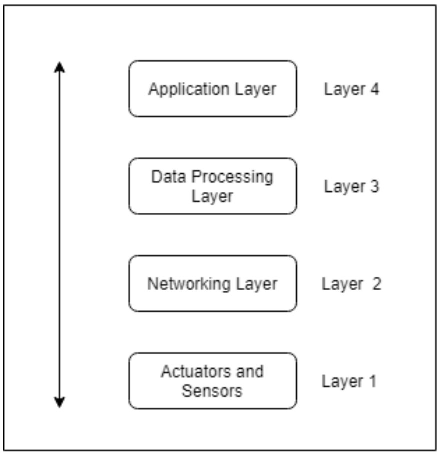
In the recent years drowsy driving is one of the major reasons of road accidents in the whole worldIt is very important to detect the drowsiness of the driver and alert him in order to save life and property. This paper presents a drowsiness detection system for automotive drivers and a detailed analysis of widely used classification techniques. Alcohol detection system is used to overcome the accidents due to drink and drive. Face being the important feature of humans; it is essential to detect the face accurately by overcoming the challenges of various expressions, head orientations etc. Various classification techniques are used to detect the eye, position of the eye and probability of openness of the eye determine the eye state. Different techniques are used to classify eye in three states like open, close or drowsy to give efficient results. Various levels of drowsiness are used to alert the driver, sound alerting system is used to keep the driver attentive by enabling a beep sound when driver drowsiness is detected. Voice alerting system is used to determine the drowsiness of the driver based on the responses given by the driver when the driver is drowsy. Also, we have discussed various algorithms that are used to detect face, eyes and eye state. This review paper provides a different approach to safeguard the driver and their vehicle. Hence, we can avoid road accidents.

Keywords: Alcohol Detection, Classification Technique, Drowsiness Detection, Eye Detection, Face Detection

Introduction

Internet of Things (IoT) is a system of interrelated computing device capable of transmitting data across the network without any human interference. IoT Architecture comprises of four layers.

Figure 1: IOT Architecture



Four layers of IoT consists of the following:

In Layer 1, Sensors are used to receive information from the system and actuators respond to the instructions that are obtained from the system, giving the ability to process signals. In Layer 2, Network layer known as transmission layer is used to transmit the information from sensors to data processing layer. The transmission can be wired or wireless.

In Layer 3, Data processing layer which is also known as Middleware layer where the information is sent to the application layer and confirms if the data is sent by an authentic user. In Layer 4, Application layer services are provided to various applications. The services will be different based on the information collected by the sensors [1]. Various applications pertaining to smart transportation, smart city, smart agriculture, smart health, smart grid and energy saving etc. exists in IoT. Accordingly we have chosen [2] paper to discuss more on smart transportation. The recent survey by the "U.S National Highway Traffic Safety Administration" (NHTSA) reports that more than 100,000 vehicle crashes occur and about 1,500 deaths occur annually. Every year due to the increasing road accidents, many lives and property is being lost. To overcome the road accidents smart transportation is one of the challenging tasks. Smart transportation [3] will address problems such as traffic congestion, road safety, automated fare collection and restricted car parking facilities. The smart parking system, consist of smart on-site sensors is used to track and report the availability of parking spaces. The other major issue faced by the society is vehicular theft. The statistical survey [4] indicates that out of 4 vehicles that are stolen, only 1 is recovered. In order to prevent the vehicular theft a GPS device is used and the vehicle's location can be identified. The command sent from the smartphone goes to the GSM device that is connected to a controller that reduces and immobilizes the ignition engine speed. "The Intelligent Transportation System" (ITS) using the IoT framework [5] includes: the sensor system, the control system, monitoring and the display system. There is "Global Positioning System" (GPS), "Near Field Communication" (NFC), Temperature and Humidity sensors in the sensor system are linked to the Internet through a GSM network in order to monitor various locations, traffic and atmosphere within the bus. The monitoring system collects raw data from the database which transforms it into a relevant context and sends it to the respective bus driver. The display system at the bus stop shows all the commuters the background data related to bus and travel.

The smartphone based driver drowsiness system [6] includes three staged detection system. In the first stage, percentage of eyelid closure (PERCLOS) is obtained from the live streaming video frames. In the second stage, voiced to unvoiced ratio is attained from the driver through microphone when the PERCLOS crosses the threshold value. In the third stage, the driver has to respond through touch within a stipulated time when drowsiness is detected. Log file is used to record the drowsiness detected data. SMS service is used to alert the concerned person.

It is very crucial to effectively detect the driver's drowsiness and alcohol consumption at earlier stages which can prevent road accidents and save lives.

According to the researcher's knowledge, in the past years none have come up with the reviews of driver drowsiness detection system. The main contribution of this review paper is to give a detail discussion on the drowsiness detection system for automotive drivers and an analysis of widely used classification techniques. In this paper, we have presented seven segments (i.e. alcohol detection, face detection, eye detection, eye state classification, sound alerting system, voice alerting system and different classification techniques) of the driver drowsiness detection system. In the first segment, the alcohol detection system has been discussed in order to reduce the risk of drink and drive. The second segment discusses about the real-time face detection by using various techniques like Haar Cascade, AdaBoost techniques, etc. The analysis of various facial expressions like head orientations, illumination, etc. are very challenging task in this research area however, face detection is being done by efficiently using appropriate techniques. In the third segment, we have explained the eye detection system. The eye detection is used to detect the eye properly even during sudden head movements. The need for localization of eye has been discussed to determine the eye state. In the fourth segment, different techniques have been discussed to classify eye in three states (i.e. open, close or drowsy state). The eye state can be classified even with eye glasses. The fifth and sixth segment discusses about sound alerting and voice alerting systems respectively. Alerting system is used to alert the driver at different levels of drowsiness. In the last segment, we have discussed about the various classification techniques. The classification techniques are used to detect face, eye and eye state, wherein each of these techniques has their own pros and cons.

In this paper, detection of alcohol is explained in Section 2. Section 3 determines detection of drowsiness, Section 4 explains on different levels of drowsiness, Section 5 explains on various techniques to detect face, eye and eye state.

Detection of Alcohol

According to the survey given by [7] 38,000 road accidents has occurred due to alcohol consumption over past three years in India. It is very essential to detect whether the driver has consumed alcohol or not at the initial stage and the system should not allow the drunk driver to drive the vehicle. The researcher [8] has explained that the locking system has been designed and the system does not start without checking the alcohol mechanism. This implementation helps to reduce road accidents. Different types of alcohol sensors like MQ2 (Mingan Qilia), MQ3, MQ4, MQ5, MQ6, MQ135 etc., are used. However in [8], MQ3 gas sensor is been used which has faster response rate and is sensitive to alcohol. The sensor can also detect other gases like benzene, methane, hexane, carbon-monoxide and Liquefied Petroleum Gas (LPG). The author [9] has addressed that an alcohol detection device has been developed based on exhaled breath analysis. The driver's status can be monitored from the remote site. The breath sensor is comprised of various sensors that use the water vapor sensor to assess if it is human breath. MQ3 sensors are connected to smartphone where the alcohol detected data is automatically sent to the cloud. The author [10] has explained that the alcohol wearable device can sense the alcohol content and monitor. Exhaust Gas Temperature (EGT) sensors based Zinc Oxide (Zno) nanostructures is being used in the device which allows synthesis of nanostructures at room temperature. The device has high detection rate and is less prone to sensitivity. The performance of the device is high and durability is more than two months. Henceforth, alcohol wearable device is being used for continuous alcohol sensing and monitoring. The author [11] has proposed a system in such a way that the driver can start the vehicle only by wearing a seat belt and needs to pass the alcohol test by using MQ3 alcohol sensor. The system includes a GPS with which an SMS can be sent to the end users during an emergency. The retrieved SMS data will be stored in the cloud which will serve as a reporting system. This system indeed identifies alcohol consumption and helps to prevent road accidents.

Detection of Drowsiness

Drowsy driving is one of the serious issues in today's world. Around 23 percent of the fatal accidents [12] induced by the driver are not identified. In real-time, it is therefore very difficult to list probable unusual driving activities and to gain appropriate training data to construct generic unusual driving activity detectors. The first layer of the proposed Hierarchical Driver Monitoring System (HDMS) distinguishes both usual and unusual driving behaviors based on traditional models by sparse representations. Furthermore the next layer of the HDMS regulates whether the activity is drowsy driving or distracted driving.

Drowsiness monitoring systems [9] can be categorized into three categories which include: Vehicle-based,Behavior-based and Physiological-based drowsiness monitoring systems. In Vehicle-based drowsiness monitoring system, the device indirectly monitors driver efficacy, through vehicle sensors and on-board leverage. In Behavior-based drowsiness monitoring system, the device tracks the behavior of the driver by a camera to calculate the blinking of the eyes, closing of the eyes, location of the head, yawning, etc. In Physiological-based drowsiness monitoring system, various physiological signals are assessed by wearable devices Ex. electrocardiogram, electromyogram and electroencephalogram.

To detect drowsiness in real-time, detecting face and eye is very important. We will review drowsiness detection of face, eyes, eye state classification in the following sections.

Detection of Face

In real-time video streaming many objects may be seen in the video while focusing on the particular human face is challenging. The author [13] has explained the following steps that are involved in using facial expressions to assess the drowsiness condition by receiving the real-time streaming video of the driver initially and analyzing the image to evaluate the driver's drowsiness state. Firstly when the frame is considered, the frame gets converted into a gray scale image. Further histogram equalization is used to improve the image contrast for better face detection. The researcher mentioned [14] that face detection is done based on Haar-like features which are trained based on Adaboost technique. The researcher [15] has discussed that the rectangular feature is used to determine the object. Haar-like features are used for fast computation of the image. Viola and Jones [16] combined Haar-like and rectangular features to detect real time objects. Viola Jones eliminates false detection using composite features by determining a rectangular frame when a face image is selected. By using integral map the feature values are extracted from the face image. Adaboost is also used for selecting the features. A strong classifier is obtained by combining several weak classifiers which rejects false negatives at the earliest. This achieves faster processing at lower resolution. Accuracy is low during extreme bright or low light conditions. The author [17] has explained that every integral image element contains sum of all pixels in that image. The researcher [18] has discussed that Haar like feature-based classifier is used to detect face with more accuracy. Analysis is made based on the different facial orientations. The author [19] stated that detection of various facial expressions, occlusion, posing variations, aging and resolution of either stationary object frames or video sequencing images is performed. Verification and identification are two important face recognition tasks being used. For face detection, Labelled Faces in the Wild (LFW) dataset is used with domain adaptation. The fusion algorithm is validated by using UGC-JU face database. Comparison of accuracy recognition levels on various face repositories, such as ORL, PHPID, YALE, GAVAbDB, VLC, AR, UGC-JU, CURTIN, FRGC Bosphorous is done. Recognizing face in motion, identifying twins, variations in pose, having different accessories like specs, beard, hair color, partition of hair, make up; different facial expressions are some of the disadvantages. Various forensic, security technologies require greater accuracy and reliability. Even aging, facial appearance, voice, occlusion, illumination, variations, thermal image are some of the challenges. After detecting the face, we need to detect authorized or unauthorized face in order to prevent any theft activity. The researcher [20] has explained that the face and the camera must be held at a certain distance to gain more accuracy. Depending on the skin color segment, the RGB shape image can be directly converted to gradation image based on the skin color segmentation for face detection. The author [21] has stated that during skin color detection processes, each pixel is labeled as either skin or non-skin based on its color components. Morphological operator is usually implemented with structural element and standard deviation. Therefore, with different head orientations and various other factors mentioned, face will be detected.

Detection of Eye

Localization of eye is the main criteria to determine the eye state. The author [14] has explained that the eye detection is done based on object tracking method which is used to track eye. Eye detection [22] is done using “Principal Component Analysis” (PCA) at daytime and “Local Binary Pattern”(LBP) at night time. Eye detection will be tracked by combining the pupil-based bright Kalman filter with the mean shift eye tracker. Due to sudden head movement, Kalman filter eye tracker may not be able to detect eye properly due to which “mean shift tracking” will overcome this limitation. The researcher [23] has explained that “Mean shift tracking system” is an object tracking system which is used to track eye regions based on eye region intensity distributions and does not include bright pupils. Captured eye image [24] estimates the position of eyes and the probability of openness of the eye, which determines the eye state. Fatigue monitor algorithm [18] measures the eye velocity that closes in a short time. In [25], eye detection is done based on corneal reflex points. Artificial Neural Network (ANN) is used to identify the pupil’s location. Tracking of the eye [26] is done based on the pupil’s shape and edge detection. Gradient method is used for analysis of vector fields of image gradients. Eye tracking [27] can be calculated by dark and bright pupil effect in which the dark pupil is analyzed when the camera captures the image while the bright pupil is analyzed by the reflection of infrared light from the retina. The cornea of an eye will be modeled as convex mirror. In order to make the device more specific [18], another feature called the open eyes and closed eyes corner feature is used to identify the eye state. Thus, eye localization has been done based on various methods to detect eye.

Eye State Classification

One of the challenging tasks is to determine whether eye is opened or closed. The author [3] has explained that the state of the eye has been classified as either “open” or “closed” based on “Support Vector Machines” (SVM). Identification of eye state [27] is detected in embedded device based on the techniques of image processing. Cascade regression framework [6] is being used to detect the position of eye and estimates the likelihood of eye closure. Also, estimation of the eye can be done even with glasses which can still predict the eye shape. The implementation [22] has been done by combining color segmentation and morphological operations to locate the human eyes. Border contact with the regional approach is eliminated by removing the facial feature points. Classification of the eye state [28] uses

Cascade classifier and Circular Hough Transform (CHT) which differentiates between open and closed eyes. CHT helps in detecting circular eye shape. Random forest [29] and instance Classifier such as IB1 and IBK performs better when compared to other eye state prediction classifiers including open and closed state using electroencephalogram (EEG) signals from the electrode data. Infrared light is used to capture images [30] under low light conditions. Infrared (IR) provides an easy and convenient solution for eye detection which is based on "differential infrared lighting scheme". Eye tracking can be detected with accuracy and robustness even if the driver is wearing sunglasses by determining the high contrast values between the eyes and rest of the face. The use of IR illumination is safe and suitable for all drivers without any side-effects. Hence, with the help of eye state classification, i.e., opened or closed eyes, the drowsiness detection of the driver becomes easier.

Levels of Drowsiness

Sound Alerting System

In order to alert a drowsy person, a sound alerting system is needed. GPS application [31] helps to reduce the rate of accidents that provides "buzz" sound to alert drivers that there is a dangerous corner ahead. This helps the driver to slow down the vehicle by hearing the alert sound. Also, the system provides closest emergency places when any adverse consequences occur. A low-cost Forward Collision Alert System (FCAS) [32] in real time is proposed to reduce road accidents. By determining the speed of the car in front, the FCAS warns the drivers when their car gets too close to the front vehicles by a loud beep sound. The FCAS is embedded in Raspberry Pi. The system alerts [33] the driver by sound and warning light when the driver's eye is closed for certain period of time. The widespread introduction of this form of system would minimize the number of road accidents caused by the exhaustion of drivers, thus saving countless lives and minimizing the socio-economic costs associated with these tragic events.

Voice Alerting System

Voice response [34] of a person is used for assessing the fatigue level. These findings are confirmed using measurements based on the EEG. The experiment is carried out in such a way that a sentence must be repeated at various stages. Specific parameters such as unvoiced, voiced and response time are analyzed based on these responses. Mel Frequency-Cepstral-Coefficients (MFCC) [35] is used for parts of speech in silence, articulated and unvoiced. Those were calculated at five separate levels along with the response time. The ratio voiced to unvoiced is said to diminish with increased fatigue. These parts have been segregated using the classifier called Gaussian Mixture Model (GMM). The findings were checked according to EEG parameter. The relative strength of the EEG signals [36] is measured at various levels. The association between Speech and EEG dependent measurements is analyzed in the experiment at different stages. The accuracy of the feature extraction [37] is done based on the modeling which is implemented using MFCC and Hidden Markov Model (HMM) for two kinds of connected word and continuous speech. The result shows the accuracy for the connected word is approximately 69.22% and continuous word is 50%. The speech recognition [38] interface was plugged-in based on Google Services. It can detect the driver's 'yes' or 'no' phrases. The android application would ask driver if he / she have really turned the head, closed the eyes, or yawned after any recognized hazardous state. Based on the response provided by the driver, the system analyses the drowsiness levels. The accuracy of image processing algorithms depends proportionally on certain factors, including people's diversity (i.e. different expressions on face, reflections on glasses), various lighting conditions (i.e. insufficient lightning shadows, shifting backgrounds) and driving vibrations. Thus, these constraints can avoid many road accidents. It is very important to alert the driver when needed. We can also alert the vehicle's owner by sending SMS and email alert.

Various Techniques to Detect Face, Eye and Eye State

Haar-like features classifiers

Haar-like cascade is used [39] for face detection from live video streams. Emotion Analysis is analysed using Haar-like cascade. Since Haar-like cascade is based on the same Haar wavelet principle, it's called Haar-like. In order to test the system, frontal face video streams were being used from multimodal Database for Emotion Analysis using Physiological Signals (DEAP). The input video is transformed into grayscale and classification is done based on Haar cascade classifier to detect face. The method was implemented using python with Open CV method. The face detection rate using this technique is accurate and also the detection rate is fast. The Haar-like principle [40] is based on feature detection; the key advantage of this approach is the calculation using the integral representation of the rapid sum. The distinction lies between the number of white pixels and the sum of black pixels. The edge orientation image [40] is another method used in for detecting face. From the face model, the edge orientation map is extracted and compared from an input image against the edge orientation map. New Haar-like features [41] are used to improve weak classifier and weight updating method is used to improve face detection by reducing the false detection rate. This classification overcomes misjudging of faces. Weak classification is improved by reducing the error rate. The detection rate is higher for both positive and rotating faces. Three additional weak classifiers are combined with Haar cascade algorithm [42] to increase the efficiency of face detection. The mentioned weak classifiers are based on eye detection, mouth detection and skin hue histogram matching. A primitive Haar cascade classifier processes the images of the people without any false detection. A weak classifier based on eyes is used to remove a non-human face which helps in specifying the eye state. Next, mouth detection is used to remove any existing false positives. Finally, skin hue histogram is used to remove further false positives and non-human faces. Henceforth, Haar cascade classier gives more efficiency and improves the detection rate.

LBP Algorithm

Local Binary Pattern (LBP) algorithm [43] is used to detect face and eye state classification by finding the key points in the images and by extracting specific features from the face. LBP is combined with Histogram of oriented gradients (HOG) to improve performance. The author [43] focuses on two aspects, firstly the author has addressed that the face detection can be improved by removing the localization error. Secondly, neural architecture has been proposed for image pattern classification. Hence, these solutions give more image information like face, eyes which give better performance.

CAMSHIFT Algorithm

In color image sequences, the Continuously Adaptive Mean Shift (CAMSHIFT) algorithm [44] is used to monitor color-based object with a known hue. By applying the mean shift by adjusting the parameters of the target distribution, CAMSHIFT generally tends to detect the particular modes in the probability distribution of face image. Thus, Camshift algorithm is used to calculate the target center which gives the probability distribution of an image.

AdaBoost Algorithm

AdaBoost stands for 'Adaptive Boosting' [45] which is used to solve classification problems and transforms weak learners to strong predictors. The Adaboost algorithm is used to determine the region of the human face and locate the pupils. To detect eye states, enhanced template matching is used. The method of AdaBoost is sensitive to noise data and anomalous data. Therefore, this method can be combined flexibly with any technique to search for weak hypotheses. It can provide a set of theoretical guarantee of learning by providing sufficient data and reliable moderate precision.

Artificial Neural Networks

The Artificial neural network (ANN) model is used to detect the driver's drowsiness [13] by using the steering wheel data. When the driver is alert, he will make subtle adjustments to the steering wheel, resulting in minor changes in steering wheel angle. When the driver is drowsy there will be large change in the steering wheel angle and if the same is prolonged for more than 10secs, then the driver is said to be drowsy. The author [46] explains that forward neural networks are being used to detect face. Gabor wavelets are used to classify feature points. A convolutional neural network is indicated by extracting feature vectors. The processing cells are said to be shunting inhibitory neurons which are used in classification and non-linear regression. Thus, ANN helps in detecting the face and detecting the drowsiness based on the steering wheel angle.

Conclusion

The primary aim of this research work is to bring to light the review of driver drowsiness detection in real time. Many road accidents occur due to drink and drive for which the researchers have mentioned various alcohol checking mechanisms which helps in reducing the road accidents. To evaluate the driver drowsiness in real-time streaming video, analyzing the driver's face is important. The researchers has surveyed various procedures for detecting the face in a better way. Detection of eye is done based on object tracking method. To determine the eye state position of the eyes, probability of openness, closeness and drowsiness of eye have been evaluated. Eye localization is done based on various methods to detect the eye. Various levels of drowsiness (i.e. sound and voice alerting system) are being determined to alert the driver. The sound alerting system is used to alert the driver by enabling a beep sound when the vehicle gets too close to the front vehicle. Voice alerting system is used to analyze the driver drowsiness by having interactive sessions (i.e. interacting with some general questions) with the driver. Based on the responses attained from the driver, drowsiness level will be detected. We have presented various techniques based on Haar Cascade,LBP Algorithm, Camshift algorithm,AdaBoost Algorithm and neural network model. In the low light conditions, infrared light helps the system to detect driver drowsiness. This drowsiness detection system is also applicable to monitor the face in lifts and ATM centers by sending an alarm if any consequences occur to the general public.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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