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Review On Visual Cues-Based Methods For Driver Fatigue Detection

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Abstract: Fatigue is a widespread issue that causes cognitive and physical performance impairment and poses risks in various areas of the transportation industry. Visual cues provide valuable information for fatigue detection and monitoring due to their non-intrusive nature and the ability to capture small changes in a person's appearance and behavior. Visual cues-based fatigue detection methods are approaches that use various visual indicators to detect and assess fatigue in an individual. Various methods for using visual cues to detect fatigue in an individual have been developed using technologies such as computer vision and machine learning algorithms. This paper discusses state-of-the-art driver fatigue detection using visual cues-based methods, how these methods can be used to address an important road safety issue, and how they can transform the way driver alertness is monitored, thus avoiding accidents caused by fatigue.

***Index Terms* - Driver fatigue, detection methods, visual cues.**

I. Introduction

Drivers under the influence of fatigue express certain specific behaviors which are visually identifiable. To interpret fatigue from these visual cues, machine vision is normally employed. Machine vision methods utilize a camera and image extraction and processing methods to identify typical characteristics of the driver's level of vigilance. One of the unique features of this method is that it can detect driver fatigue at an earlier stage. (Ji, 2004)

Driver face monitoring system consists of the following main three parts

1. Camera with illumination

2. Hardware and processor

3. Software

The driver face monitoring systems must be able to work under all lighting conditions. It also should not provide a distraction to the driver's normal tasks. Hence near-infrared illumination is used for the purpose. Another advantage of using IR illumination is that it helps to locate the pupil of the driver very easily because the human retina is highly reflective of IR radiation. The camera used should work in the selected illumination spectrum. Visible light is rarely used for illumination.

A hardware system includes an interface and a processor. Embedded systems are normally used. Normal microprocessors cannot be used because image processing requires huge computation power. DSP or FPGA-based hardware is used.

Software used in driver face monitoring systems consists of two parts, image processing and decision-making algorithm. Image processing algorithms consist of the preprocessing phase, facial components detection phase, and symptom extraction phase. From the extracted symptoms, the decision-making algorithm identifies the level of fatigue of the driver and generates an output.

II. UPPER BODY IMAGE-BASED DETECTION METHOD

Movement of the upper body can be used as a reliable method for identifying driver fatigue. The features that are particularly indicative of driver fatigue are

1. Driver arm position
2. Face Orientation
3. Facial expression
4. Eye behaviour

Initially, the image of the driver is extracted from the background using image subtraction and optimization methods. The contours of the body are located. After that, the edge of the arm is determined. Classifiers are used to identify four positions of arm; arm up, arm down, arm left, and arm forward.

Eye gaze and eye direction are deducted by processing the image. Iris detection is done by using filters that are responsive to the center of the iris. Gaze direction was obtained by comparing the iris to the corner of the eyes. Eye blinking was identified by using an SVM which was trained to detect open eyes from closed eyes.

Head orientation is detected from an accurate face model. The model is generated by identifying the root of the head by combining a depth map and color image. From the face model, head orientation is obtained. Yawn is identified by locating the mouth by detecting the level of distortion of the features of the face (Craye, 2016).

Fatigue is determined by evaluating the three behaviors namely the percentage of eye closure (PERCLOS), yawning, and head nodding using trained SVM and HMM classifiers.

PERCLOS is calculated in a 3-minute window by the formula,

$$PERCLOS = \frac{Number\ of\ frames\ with\ closed\ eyes}{Total\ number\ of\ frames}$$

Yawn is characterized by the opening of the mouth for certain seconds. Nodding is detected by identifying the quick lowering of the head.

Assari (2011) uses facial expressions to detect drowsiness. An infrared light-based hardware system is used for this. A video sequence frame is used for the detection process.

Fatigue data from the visual module is compared with other modules available on the vehicle using a Bayesian network (Bayesian network is a probabilistic graphical model that represents a set of random variables and their conditional dependencies) based decision-making model (Craye, 2016).

Iris visibility-based eye state and algorithm for converting it to drowsiness are explained in this work. Matlab with image processing was used for this. Viola-Jones algorithm is used to detect the nose, mouth, or upper body. The threshold value is finally converted to a binary image. After smoothing this image with filters, drowsiness is detected. The pixel ratio or number of pixels in the colour is the condition for this detection (Kahlon, 2018).

Another work proposes fatigue recognition based on yawn detection. Thermal imaging is the technique used. Face alignment is done by continuous detection of eye corners. Yawn detection is based on the thermal method in which average temperature analysis is conducted. An image database was there for the proper evaluation. Long-range thermal infrared imaging is used in this work (Knapik, 2019).

An improved multi-task cascaded convolutional network is used for the accurate position of face features. Then Res-SE-net model is used to achieve the state of the eye and mouth. This model is trained by some others. Combined PERCLOSE and OMR rule is used for the final judgment of fatigue (Wang, 2021).

A single sample condition is proposed in the work (Xiao, 2021). The camera is calibrated by Zhang Zhengyou's calibration method. The optimal camera parameters were calculated. Texture mapping technology is implemented in this work. The detection efficiency is improved by a symmetric algorithm. Detection accuracy is 20% higher than conventional algorithms (Xiao, 2021).

An algorithm based on deeply learned facial expression analysis is used for detection. A well-trained model is used for detecting 24 facial features. This module is trained by multi-block local binary patterns and the AdaBoost classifier. Then calculate the proportion of closed-eye time and yawning frequency. The fatigue state is identified using a fuzzy inference system. States like normal, slight fatigue, and severe fatigue can be identified by this method (Li, 2022).

Another paper explains a system that uses integrated facial features and gate recurrent unit judgment neural networks. Multiple images are processed by a neural network including GRU. MTCNN is used to extract facial features. Three types of various aspect ratios are calculated. Three types of head pose angles obtained with 3D face models are also collected. Based on these six features the judgement is created. The accuracy of this method is 97.47% (Li, 2023).

III. EYE BLINK FEATURES-BASED DETECTION METHOD

Eyeblink is defined as the temporary closure and opening of both eyes including movements of both eyelids. Eye blinks are generally classified into three.

Voluntary eye blinks refer to the type of blinks that involve the individual's intentional control.

Reflective blinks are the type of blinks that are induced by external stimuli such as flashing lights, loud sounds, etc.

Spontaneous eye blinks are blinks that occur unconsciously and periodically. This type of blink can reflect the mental status induced by the task (Ogata, 2016), (Marquart, 2015).

Commonly used blink parameters are PERCLOS, blink frequency, blink duration, and blink latency.

In this method, the image of the driver is acquired using a micro-camera and preprocessed using the histogram equalization method. Infrared illumination is used to facilitate the detection of faces irrespective of natural illumination conditions. The pre-processing of the captured image is done to eliminate the noise (You, 2017).

Eye detection is done by using AdaBoost, template matching, and eye validation algorithms. Eye features are then extracted from the detected image using the Gabor filter. The blink period is estimated from the eye features. A normal driver will have fast and constant blinks. If the driver is sleepy, he will have slow blinks. A very sleepy driver will have long blinks. From the blink period, eye blink frequency and duration are calculated to estimate the driver's fatigue level (You, 2017).

DriCare system detects yawning, blinking, and duration of eye closure using video images. The conventional algorithm is KCF (Kernelized Correlation Filters Algorithm). A new accurate face-tracking algorithm is used (Multiple Convolutional Neural Network). 68 key points-based facial region detection was proposed. The DriCare can alert the driver with an accuracy of 92% (Deng, 2019).

A system with a video camera is used for detection. Video files were converted to frames. Measuring the intensity change in the eye area, detects the state of the eye, whether it is open or not. A five-second close will be the signal of a sleeping driver (Devi, 2008).

IV. HEAD POSTURE AND EYE STATE-BASED DETECTION

Driver's head pose can provide information about the level of attention. One of the symptoms of drowsiness is head nodding. While drowsy, the head gradually bends. If the orientation of the driver's head changes excessively from its normal state frequently, it can be considered as a symptom of fatigue. A three-dimensional model of the head is required for finding the head orientation (Zhang, 2015).

For determining the driver's head pose, the face has to be detected first. An RGB-D camera is used for this purpose. RGB-D cameras can provide RGB data along with depth data. Head detection is done by processing the depth data. A head position is estimated by the 3D head pose estimation method. Eye position is located. Eye state is obtained by processing the image using a local binary pattern (LBP) classifier and SVM-based algorithm. Eyeblink frequency is estimated from the eye state (Zhang, 2015).

The fatigue parameters calculated from the processed data are combined to form a composite fatigue index using a Bayesian network which can detect driver fatigue accurately (Zhang, 2015).

The early warning system is established by analyzing the eyes and mouth of the driver. The VJ detector algorithm is used for detecting the face. And MB-LBP feature is used to find the eye area. Tracking of the eye and mouth was carried out by the Kalman filter algorithm. The ratio between the axis values of an ellipse fitted for the eyes was converted to a threshold. From this, it is possible to detect the state of the eye and mouth (Tang, 2016).

Another work uses a vision-based technique for detection. The system consists of modules for head-shoulder detection, face detection, eye detection, eye open estimation, fusion, PERCLOS estimation, and fatigue level classification. Spectral regression-based eye openness detection and fusion algorithm to estimate eye state are the basis of this work (Mandal, 2016).

Two cameras to detect driver fatigue in real time. One camera is for identifying head position and the other is for extracting the data related to the position of the mouth. Using the second camera and fast image processing algorithm the work proposes a method to locate the driver's face. Using haar- like feature, the driver's mouth was detected. Then track the state based on historical position. Yawning is detected by mouth height to width ratio (Li, 2009).

V. EYE FIXATION DURATION AND PUPIL DILATION DETECTION METHOD

Eye movements are mainly divided into four categories

1. Saccades
2. Smooth pursuit movements
3. Vergence movements
4. Vestibulo-ocular movements

Saccades are rapid and spontaneous movements that abruptly change the eye fixation point. Smooth pursuit movements are slower tracking movements of the eyes for keeping a moving stimulus on the retina. Vergence movements are the movements of the eyes for aligning the retina to visual targets located at different distances. Vestibulo-ocular movements stabilize the eye movements by compensating for head movements (Purves, 2012).

Eye fixation is the process of maintaining the visual gaze on a single location. Fixation is composed of slower and minute saccades to help the eye align with the target. Increased fixation duration indicates a mental workload. Increased fixation produces a narrowing of the focus of a driver. Fixation duration also increases when a potential hazard during driving arises in front of the driver (Martinez-Conde, 2004), (Marquart, 2015).

Pupillometry is the method of measuring pupil diameter which is considered as an indicator of mental workload. Small fluctuations of pupil diameter of about 0.5mm which are involuntary are called a task-evoked pupillary response (TEPR). Average TEPR is a reliable source of mental workload (Marquart, 2015).

In this method, the index cognitive activity (ICA) method is used to identify TEPR. ICA is a signal processing method that uses different reflex properties to separate the effect of illumination and workload on pupil dilation. The value is calculated using an algorithm using pupillometry (Marquart, 2015).

Hough Transform, AdaBoost, and PERCLOS algorithms can detect drivers' eyes and the colour of their skin. This work discusses the influence of spectacles on the detection and level of success of these algorithms under various degrees of illumination (Mu, 2022).

VI. DRIVER POSTURE TRACKING BASED DETECTION METHOD

Driving posture refers to the position of the body and how a person holds his body during driving action. Body posture provides information about the driver's state. For example, leaning backward indicates a relaxed position, and leaning forward shows concentration. The driver may also change posture in preparation for any specific task that arises during driving. A drowsy driver will make sudden corrections to lane deviations and try to correct the sitting pose suddenly while avoiding falling asleep (Moeslund, 2011), (Jiménez-Pinto, 2013).

This method is divided into three stages

1. Image capture
2. Driver detection and pose tracking
3. Alertness measurement

Image capture is done by using a camera. Infrared illumination is provided and the camera is modified accordingly to capture IR images and to eliminate other sources of radiation. The image is preprocessed to reduce the image size to suit the pose detection algorithm to work in real-time (Jiménez-Pinto, 2013).

Driver detection is initialized by the detection of the driver's face by the Viola-Jones detection method. Distinct corner points on the face (eyebrow corners, moles, scars, beards, etc.) are detected and the salient points grid (SPG) is computed. The SPG is modeled in 3D space to replicate the driver's head-torso kinematics. Driver's initial position is located from interpupillary distance and new positions are estimated within the expected regions. (Jiménez-Pinto, 2013).

Driver non-alertness is identified by locating instances when the driver's head is not staring forward and by calculating PERCLOS. Driver pose magnitude is calculated and it shows the level of drowsiness of the driver. Pose magnitude increases when the driver is in a semi-drowsy state. PERCLOS is calculated from a running window of one minute to identify the driver's fatigue (Jiménez-Pinto, 2013).

Another work proposed a Wi-Fi signal-based fatigue detection system. It can detect fatigue symptoms in the vehicle. A self-adaptive method is applied to recognize the features of the body of drivers. This work uses the Hilbet-Huang transform-based extraction method. Accuracy is estimated at 89.6% with a single driver (Jia, 2018).

Human pose estimation was done from various video sequences. From this fatigue related features are extracted. Information entropy and sliding window algorithms are used to obtain clear fatigue values. Support Vector Machine suggests the state of fatigue (Li, 2022).

VII. CONCLUSION

Fatigue detection by visual cues-based methods provides a non-intrusive and valuable way to detect and monitor fatigue in people. Advancements in computer vision technology, machine learning technology, and sensor technology have significantly increased the precision and reliability of visual cues-based fatigue detection systems. Fatigue detection systems use a variety of visual indicators to detect fatigue. These methods can be improved with the help of technology to increase the accuracy and monitoring capabilities in real time.

Further research and development promise even more advanced and practical applications that will improve safety and performance in various industries. Privacy and ethical considerations must be addressed during the development and deployment of such systems.

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