Improved Method for Driver Drowsiness Detection Using Hybrid Template Matching Algorithm

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Abstract: ***Now day's car accidents because of driver distraction and fatigues are causing the many damages to human being. Therefore, recently different methods introduced by many researchers for early detection of driver drowsiness in order to prevent accidents on road. The methods are commonly known as driver face monitoring methods introduced for driver fatigue detection as well as accident avoidance. Most of methods are based on image processing concepts in which images of driver face are captured, and then extracted the eyes, mouth and head position of driver from input image. The symptoms for detecting the drowsiness are eyelid distance, eyelid closure over time, yawing, head orientation, head nodding, yawning etc. In this paper our goal is to present novel framework for detecting the driver drowsiness or fatigue efficiently using the Viola Jones Algorithm for detecting mouth, eyes, nose detection and face detection along with template matching approach. Viola Jones method helps to find face, left eyes, right eyes, nose, and mouth points on input image. Local features are extracted and used for template matching process to detect whether mouth is yawing or whether eyes are open or closed. Most of existing methods uses either yawing technique of eye blinking technique for driver drowsiness detection; in this paper we proposed hybrid method which is combination of template matching of open eyes and closed and template of yawing.***

Keywords: Driver Drowsiness, Face detection, Eyes detection, Mouth detection, Fatigue, Yawing, Viola Jones

1. Introduction

ITS (intelligent transportation system) is having goal of reducing the accidents and improving the public safety. Driver fatigue or distraction is main reason in many accident cases on rural roads. Drowsiness or fatigue breaks the driver concentration while driving which resulted into loss of decision making functionality for controlling car. From general research and polls, it is assumed that for continues driving case, driver is fatigued after 2-3 hours and hence the performance of steering is deteriorated. The driver drowsiness is more in midnight, after lunch, afternoon hours as compared to other times in day. Also the factors like alcohol; drugs etc. are responsible for loss of driver concentration. All over world, various countries presented there different statistics over the accidents those happened due to driver drowsiness and distraction. Generally, around 20 % - 30 % of accidents are done due to the driver drowsiness and distraction.

Now, the concepts of fatigue, drowsiness and distraction from the viewpoint of physiology and psychology are explained. However from the viewpoints of physiology and psychology, the concepts of fatigue and drowsiness are different, but in the literatures found in the field of ITS, fatigue and drowsiness are synonymous terms. Hypo-vigilance is another term means lack of consciousness and may include drowsiness, distraction or both.A precise and scientific definition for fatigue has not been presented yet; therefore, there is not any quantitative criterion to measure it. Fatigue occurs in three different types: sensory fatigue, muscle fatigue and cognitive fatigue. Sensory fatigue and muscular fatigue are only measurable and there is not any way to measure cognitive fatigue [7, 9]. Although a precise definition for fatigue is not presented yet, but there is a relation between the fatigue/drowsiness and body temperature, electrical skin resistance, eye movement, breathing rate, heart rate and brain activity [3]. However, the best tool for measuring fatigue and drowsiness is brain activity monitoring, but in this approach, brain signals must be received from the electrodes that connected to the driver head which make it as an intrusive approach. After monitoring of brain activity, the most significant symptom of fatigue is appeared in eye. According to the researches, the latency between the visual stimulus and its response is one of the main measures to determine the consciousness. This latency is known by a parameter called Psychomotor Vigilance Task (PVT) that shows the response speed of a person to his/her visual stimulation. Researches show that there is a very close relation between PVT and the percentage of closed eyelids in a period of time. The percentage of eyelid closure over time called PERCLOS [8]. Therefore, there is a close relation between fatigue and percentage of eye closure. Driver face monitoring systems use this relation to estimate driver fatigue/drowsiness.

Monotony of a certain task can reduce the concentration of person and may cause distraction. Monotony is caused by three main reasons: (1) lack of personal interest, (2) doing a repetitive task for long time and (3) external factors (like talking with mobile phone). Monotony in driving usually is caused by the second and third reasons. Prolonged driving on highways with flowing traffic has a negative effect on driver concentration. In this case, driver is not fatigued, but due to the monotony of driving, his/her concentration will gradually be decreased and the driver will not have a careful control on the vehicle. Driver distraction can also is caused by talking to people or mobile phone and listening to music [7, 9]. Driver distraction can be estimated by head and gaze direction determination. The main problem for distraction detection is that if head is forward and eyes look toward the road, the driver does not necessarily pay attention to the road. In other words, looking toward the road is not paying attention to it [9].

Due to the importance of early detection of driver fatigue and drowsiness to avoid accidents, many researches were done on this subject in the past decade. The researches on the methods for driver distraction detection are also being done, but are less developed than the methods of driver fatigue detection. However, fatigue and distraction can be considered as two separate concepts, since both of these factors reduce driver alertness; both categories are investigated in some studies. We can divide the most important approaches for fatigue/distraction detection into three categories: (1) approaches based on bioelectric signals (e.g., EEG and ECG), (2) approaches based on steering motion, and (3) approaches based on driver face monitoring. These approaches can be investigated from different viewpoints including ability of fatigue detestation, ability of distraction detection, accuracy, and simplicity and detection speed.

Distraction detection is more difficult than fatigue detection, but the approaches based on steering motion and the approaches based on driver face monitoring can estimate the lack of the driver concentration in limited circumstances. Comparison between the main approaches is briefly listed in Table 1. The approaches based on bioelectric signals have a very good accuracy and speed at detecting fatigue, but they are usually intrusive. Additionally, the driver distraction cannot be identified from his/her bioelectric signals using current technology by now. The approaches based on driver face monitoring have lower accuracy than the approaches based on steering motion, but they can detect driver fatigue and distraction earlier. Three main approaches for driver fatigue/distraction detection are compared subjectively in Table 1.

Table 1: Different domains of driver's drowsiness detection

	Approaches based on Bioelectric Signals	Approaches based on Steering Motion	Approaches based on Driver Face Monitoring
Fatigue Detection	Yes	Yes	Yes
Distraction Detection	No	Yes	Yes
Accuracy	Very Good	Good	Moderate
Simplicity	Difficult	Relatively Easy	Easy
Detection Speed	Very Fast	Slow	Fast

In this paper we are introducing new hybrid template matching method for detection of drowsiness for preventing the accidents on rural roads. Existing methods uses either template matching of open eyes and closed eyes or yawing frequency of driver. In proposed case we are storing the templates of open eyes, closed eyes and yawing in different positions. The input frames will be matched for this template and based on counter of closed eyes and yawing detection of driver drowsiness is done. In rest of paper, section II presents the survey of different image processing based methods for driver drowsiness detection. In section III, proposed architecture and algorithms discussed. In section IV, practical environment, dataset related details, performance metrics and expected results. In section V, conclusion is made based on theory with future work.

2. Related Work

In this section we are presenting the different methods introduced for driver's drowsiness detection. These methods are categorised into different categories based proposed approach such as face detection based methods, eye detection based methods etc.

2.1. Face Detection Methods

There are two types of face detection methods used for drowsiness detection such as feature based techniques and learning based techniques.

In feature based methods, face detection is done by using the features of image such as pose, face rotation, ambient light. Such techniques are basically used for one face in image. The main problem in this method is that the background is assumed uniform. If the background is complex or cluttered, face detection is failed.

In [1], author Wang et al. proposed method in which position of face was determined by the vertical projection of the gray level image. In this paper, the driver background was assumed non-cluttered while the face has lighter pixels than background.

On the other hand, learning based face detection techniques are based on number of training samples. These methods improve the face detection accuracy, but having more computational complexity.

In [2], author Viola et al. presented an algorithm for object detection, which uses very simple features named Haar-like features. In this algorithm, many numbers of Haar-like features are extracted from the image, and a number of effective features are selected using AdaBoost algorithm, and then these features are processed in a hierarchical structure similar to the decision tree. Due to the simple extracted features and selection of the best features, this algorithm is relatively fast and robust. This method is very fast and efficient as compared to other methods.

In [3], author Hamada *et al.* used neural networks for face detection. In this method, an edge detection method was applied on the image, and then the result image was scanned by a window and is evaluated by neural network to detect face.

2.2. Eye Detection Methods

Eye detection is most vital part for drowsiness detection as it is commonly used as symptom. Hence eye detection is required before processing of eye region. There are three main types of Eye detection such as imaging in IR spectrum, feature based methods and other methods.

Imaging in IR spectrum based methods is quick and relatively accurate methods for eye detection. In these methods, physiological and optical properties of eye in IR spectrum are used.

In [4], author Zhu et al. proposed imaging in IR spectrum based method for eye detection, except that after initial eye detection, used Support Vector Machine (SVM) for increasing accuracy of eye detection. In this paper, various SVM kernels are investigated and it is shown that Gaussian kernel has the best accuracy.

In [5], author Zhao et al. used only one IR light source for eye detection which was located along the optical axis of the camera. According to position of the light source with respect to driver, pupil is always seen brightly in the image. Therefore, eye locations were detected using opening morphological operation and subtracting the resulted image from the original image. Then, some candidate points were extracted by applying a threshold on difference image and then using connected component analysis. In addition, SVM and Generalized Symmetry Transformation (GST) were used to increase the accuracy of eye detection. The eye locations were determined by combining the results of SVM and GST.

In feature based methods for eye detection, features are utilized in simple way. In [6], author present approach with assumption that eye is the darkest points in face, eye location was determined. For this purpose, after binarization of face image, large contours are detected. The first central moment of two largest contours of face image is determined as eye center.
In [7] [8], author Smith et al. obtained binary image of face region after face detection based on the skin color. Binarization of face region was performed based on the skin color and causes eyes appear black, while other parts of the face appear white. Then, the connected component analysis was used to increase the accuracy of eye detection.

In [9] [10], author Roshani Tabrizi et al. proposed an eye detection algorithm that detects eye in the HSV color space. They also proposed another method in [42] that is based on the method proposed] for the precise eye detection. In this method, a linear transform was applied on image in YCbCr color space, and then the transformed image was converted to binary image. This method has a very good accuracy for eye detection in color images, but it fails when illumination of environment is low.
In [11], author introduced project based method in which projection was not applied directly on image (either gray-level or binary image), but projection of the edge detected image was used. This method is less sensitive to face color, but it fails for detection of eyes with sunglasses.

Other methods are introduced by few authors for eye detection, however such methods are very time consuming. In [12], author Batista detected eye region based on a face model. For this purpose, the estimated eyebrow area was separated from face image and was processed with Sobel edge detection operator. Then, the eyebrows area was detected by calculating projection of edges of image. Because eyes region is always under eyebrows area, eyes region was detected. It was assumed that pupil is the darkest area in eye. With this assumption, after intensity improvement, image binarization was performed and after edge detection, pupil was detected.

In [13], author proposed two different methods for eye detection in day and night. The proposed method for eye detection in day is based on searching an elliptical gray-level model in the top half of face region. In night mode, an IR lighting and imaging system was used which can detect pupil directly. It seems that the combination of these two methods make the system robust and efficient.

2.3. Face Components Detection Methods

In [14] [15], author Bergasa et al., extracted the nostrils for determination of head direction. In this method, camera was located slightly lower that driver face while nostrils are often visible. The most important property of nostrils is blackness with respect to face skin. Thus, by applying a threshold on nose area, nostrils are detected. This method is failed for nostrils detection of black people and people who have mustache.

In [16] [17], authors uses the salient points of face are detected after face detection. In these researches, the salient points are tracked over time. Thus, according to the relative position of salient points, hypo-vigilance symptoms are extracted.

2.4. Drowsiness Detection Methods

In [18], author search window was used for eye tracking. This system was developed on a PC104+ and could achieve a processing speed of 10 fps. The main disadvantage of this system is that in the cases of rapid movement of head, tracking is disrupted and detection should be done again manually.

In [19], author Rang-ben et al. used a template matching method based on Hausdroff distance for eye tracking. Accordingly, the similarity between template and search window was calculated, and the point with the lowest distance was determined as eye location. Tracking speed of 10 fps was reported using this method.

In [20] [21], author presented eye tracking method using template matching. In this method, the driver eye template in both open and closed status for the left and right eyes was determined by subtracting two images during blinking. Then, entire face region was searched using correlation method for eye detection. Correlation method is independent to intensity changes of input image or template image.

In [22], detected eye region was chosen as eye template to use in the next stage of eye tracking. Eye tracking was done based on calculation of Sum of Absolute Difference (SAD). In this method, size of search area is 10 pixels larger than size of the eye template.

In [23], face tracking was done using Kalman filter based on a number of scale independent features. This method assumes that face components are on a plane, and the changes of face image in each frame can be estimated using an affine transform.

In [24], author Zhang et al. used UKF filter for eye tracking. The main advantage of UKF filter is accurate estimation of eye location with low computational complexity. Tracking error of this method was reported as 0.5%.

In [25], closed and open eyes were detected based on calculation of image projection of eye region. This method is relatively simple and has good accuracy.

In [26], a method was presented which detect closed and open eyes based on edges of eyelids and eye corners. Computational complexity of edge detection is slightly more than projection but it seems that its accuracy is not much different.

In [27], optical flow was used for detection of eye closure. In these methods, opening and closing state of eyelids was detected based on calculation of optical flow.

In [28], author Ji et al. computed Gabor wavelet coefficients at 8 fixed points around mouth for detection of open mouth. Gabor wavelet coefficients have different values in a closed mouth state compared to open mouth state. Thus, by comparing these coefficients, driver yawning was recognized. Number of yawning in a certain period of time was used as a symptom for drowsiness detection.

In [29], author Ji et al. used one camera to determine head orientation. For this purpose, three-dimensional model of head was extracted using pupil properties. The pupil properties including shape, size and its gray level and the distance between two pupils will change when head is rotated. Therefore, direction of head rotation was determined with an error of 15 degrees.

3. Proposed Methodology

3.1. Problem Definition

From the past history and records, 30 % of road accidents are happened because of driver fatigue or drowsiness and distractions. Therefore there must be an automated technique which can able to detect driver drowsiness and inform him to prevent accidents and other damages. Since from last 15 years, different automated techniques based on image processing were introduced by different authors for detecting the drowsiness of drivers. However most of methods are suffered from limitation of less accuracy and more computation time. Almost all methods are based on face component extraction such as eyes, mouth, and nose for detection of drowsiness. Therefore accuracy detection of face components becomes for system accuracy. Detection of drowsiness is done by different ways such as template matching, eye blinking, yawing based, technique based etc. Many methods used one of these matching methods for detection of fatigue. Therefore accuracy is still concern for driver distraction detection.

3.2. Proposed Work

To improve the driver drowsiness detection accuracy, in this paper we are using efficient framework in which face components are extracted using efficient, accurate and fast method of Viola Jones. This method is more robust as compared to other existing methods of face component extraction. After that we are using local features such as histogram of oriented gradients (HOG) and interest points. These features are stored for open eyes, closed eyes and yawing frames in dataset. These features later together used to check whether input frame is having closed eyes and yawing. The accuracy of proposed approach is improved as we are considering two factors closed eyes and yawing. Below figure 3.1 is showing the architecture of proposed approach.

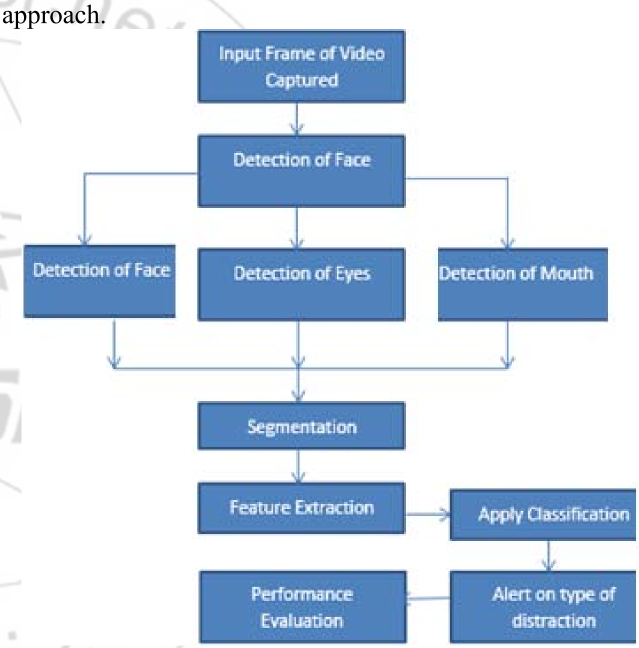

Figure 3.1: Proposed system architecture

In this proposed method, template matching is done by using templates of closed eyes, open eyes, yawing face, normal face. The current state of driver eyes and face are compared with templates stored in database, if its matches and cross the certain threshold value of consecutive closed eyes frames and yawing then system will through the alarm of drowsy detection. The algorithms used for face component detection are based on Viola Jones and feature extraction is done by using HOG features. The detailed discussions of these algorithms are out of scope of this paper.

4. Practical Environment

4.1. Implementation Platform

For implementation of proposed approach, we will use MATLAB simulation tool 2013a onwards under Windows 7 or onwards operating system with 4 GB RAM and 40 GB minimum hard disk. Practical work is out of scope of this paper.

4.2. Dataset Used

[We used Caltech face data base] with different types such normal faces, yawing faces, eye blinking, head rotation faces. This are actually different types of distractions. Frontal face dataset. Collected by Markus Weber at California Institute of Technology. 450 face images. 896 x 592 pixels. Jpeg format. 27 or so unique people under with different lighting/expressions/backgrounds.

4.3. Performance Metrics

There are two main performance metrics which we are going to consider for evaluating the proposed approach of detecting the driver's drowsiness such as False Positive Rate (FPR) and False Negative Rate (FNR). For face and eye detection algorithms, these criteria are also used to determine the accuracy of the algorithm. Generally, FPR and FNR are used for complete evaluation of a detection algorithm.

FPR, also known as false alarm ratio or type I error, is the system error rate in the false detection of samples; while FNR, also known as type II error, is the system error rate related to samples that falsely not detected. Below are formulas of computing FPR and FNR.

$FPR = FP/FP+TN$
$FNR = FN/FN+TP$

Where, FP means false positive, FN means false negative, TN means true negative and TP means true positive. In addition to this, we are considering the other performance metrics such as sensitivity, specificity and accuracy.

5. Conclusion and Future Work

In this paper, we proposed new framework for efficient and accurate detection of driver's drowsiness using face component extraction, feature extraction and template matching hybrid technique. We address the limitations of existing methods for driver fatigue detection in this paper. For future work, practical implementation, and its evaluation against existing method is recommended.

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