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Research paper

Comparison of Eye Detection Methods using Image Processing

Vijayalaxmi Biradar [1]*

[1]*Department of ECE*
[1]*Vignan Institute of Technology and Science*
**Corresponding author E-mail:laxmi81181@gmail.com*

Abstract

Driver fatigue is major factor in more number of vehicle accidents on road. Statistics from Transport Accident Commission shows that nearly 20% of fatal road accidents involve fatigue. National Highway Traffic Safety Administration estimate that nearly 2,000 deaths, 70,000 injuries and $12.5 billion of financial losses occur annually. The development of technologies for detecting and preventing fatigue at the wheel is a major challenge faced by accident avoidance systems. Measurement of fatigue becomes difficult as it becomes more pronounced. During last decade, lot of research work has been carried out development of fatigue detection system for avoiding accidents on road. It is the summary of all related work carried out, the methods and components required in this research. The drawbacks of the existing methods, advantages and limitations are discussed in this paper. There are many technologies for Fatigue detection which are divided into biological indicators, vehicle behaviour and face analysis. This paper is a part of research work on the project "Development of Non-Intrusive Driver Fatigue Detection & Warning System to avoid on road Accidents" sanctioned under Early Career Research Award sponsored by Science & Engineering Research Board ,Govt. of India ,New Delhi at Vignan Institute of Technology & Science, Vignan Hills, Hyderabad.

Keywords: *Face, Eye, Driver, Fatigue, Skin*

1. Introduction

A. Monitoring Biological Properties

This approach is to measure the physiological changes of driver such as Electro-Encephalo Graph(EEG), Electro-Cardio Graph(ECG), body temperature, head movement, pulse & O_2 saturation in blood using sensors. During the sleep time brain and heart signals are affected strongly, measuring EEG & ECG signals can give accurate drowsiness/fatigue detection. To carry out this research, electrodes need to be connected to driver's head, face or chest. In real time implementation, this approach needs to process the signal and requires wires for connection, which is another major problem. The drawback of this approach is Non-realistic, Annoying, distracting drivers and difficult to implement in real time (H.J.Eoh, et.al.,2005, C.T.Lin,et.al.,2005 & S.K.L.Lal,et.al.,2003).

B. Sensing of Driver Operation

This approach is to measure physical changes such as, sagging posture by placing sensors on back seats and steering wheels. ECG Sensors are placed on steering wheel and back seat for drowsiness detection when the driver puts hand on steering wheel. The drawback of this approach is, if driver uses only one hand than it is not possible to detect ECG signal. The ECG sensors placed on back seat are very sensitive to impedance and disturbance from environment (Xun Yu,2009).

C. Sensing of Vehicle Response

This approach is to measure the behaviour of vehicle by measuring steering wheel movement, accelerator and brake patterns, vehicle speed, accelerator, displacement which are non-invasive way of detecting driver fatigue. The drawback of this approach is, it is limited to vehicle type and conditions of driver (Xun Yu,2009).

D. Monitoring response of driver

This approach is to request the driver to send response to the system from time to time. The drawback of this approach, driver becomes tiresome and feels annoying.

Among the above discussed techniques, monitoring physiological characteristics approach gives the best results. But the major drawback is this approach is Intrusive which annoys and disturbs the driver.

E. Limitations of intrusive Systems

- ✓ Complex and extremely invasive
- ✓ Cannot be placed easily
- ✓ Poor Performance
- ✓ Disturbance & Annoying for the driver
- ✓ Non-reliable
- ✓ Sensors become noisy when comes in contact with environment.

The solution for the above mentioned problem is Non-Intrusive system. These systems depend on visual observation and hence do not affect the driver. Enhancement of public safety and reduction of road accidents are the utmost need of intelligent transportation system. Driver fatigue is an important factor for road accidents. Fatigue reduces driver perception and decision making capability to control the vehicle. In Non-intrusive system, analysis of face is

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done to detect the driver fatigue and alert the driver. Fatigue appears in the eyes.

2. Image Processing Based Techniques

The solution for the above mentioned problem is Non-Intrusive system. These systems depend on visual observation and hence do not affect the driver. Enhancement of public safety and reduction of road accidents are the utmost need of intelligent transportation system. Driver fatigue is an important factor for road accidents. Fatigue reduces driver perception and decision making capability to control the vehicle. In Non-intrusive system, analysis of face is done to detect the driver fatigue and alert the driver. Fatigue appears in the eyes.

A. Eye Detection Algorithms

Development of Eye Tracking (ET) techniques is a challenging task during the last decade. ET tracks the movement of eyes to know exactly where the person is looking and for how long. ET applications cover HCI, BCI, assistive technology, e-learning, psychology and so on. In 1879, Emile Java an Ophthalmologist described the movement of eye during reading. He observed using mirror that eye movements are not continuously along the phrase. Later in 1908, Edmund Huey built an eye tracker device using small contact lens with a hole for pupil gaze direction reading was done using an aluminium pointer connected to lens.

He used video camera to capture and study eye movements. In 1948, Hartridge developed first head mounted eye tracker. In '70s efforts were on human eye operation and number of publications decreased because methods and efforts were put on processing the data. In '80s, Personal Computer (PC) made researcher investigate new eye tracking algorithms with high speed data processing which can be used for interaction between human and computer. Levine in 1981 and Hutchinson in 1981 used this eye tracking for physically challenged people. In '90s National Football League (NFL) also used eye tracking to determine what parts of the screen were mostly viewed by football fans.

Facial feature extraction is one of the areas, where lot of research has been done in the last two decades. Face detection and feature extraction has emerged as a challenging task for computer vision field. Among all other features of face such as nose, eyebrows, mouth, eyes; eye is considered as the most salient feature because of its versatility and expression variety.

The main objective of this research is to develop a DFD system based on eye detection which is a non-invasive approach. Eye tracking has found applications in smart devices and assisting people [42,53]. The existing eye detection techniques can be classified into two categories:

i. Traditional image based passive approaches
ii. Active Infrared based approaches

In traditional based approaches eyes are detected based on unique intensity or shape/size of the eyes as eyes appear to be different from rest of the features of the face In Infrared based approaches, pupil is tracked based on the properties of pupil under different infrared illumination to produce dark/bright pupil.

Eye detection and tracking based on IR illumination are simple but effective approach. They make use of the reflective property of pupil under near IR illumination. In this approach, eye detection and tracking depends on active IR light source to produce bright/dark pupil effects. The researcher used two IR light sources to detect eyes based on differential lighting scheme [15]. The drawback of difference in lighting method was its inability to detect eyes with glasses. Later this technique was improved by brightness stabilization to eliminate glass reflection [27].

Most of these methods depend on bright/dark pupil effect. The success of these methods depend on size and brightness of the pupil, but these two methods are effected by several other factors such as eye closure, lighting conditions (external illumination interference), camera distance and face rotation which causes eye occlusion.

The absence of bright pupil or weak intensity pupil causes serious problems in eyes tracking systems. Eye tracking using IR illumination as light source requires open & un-occluded eyes, small orientation in face, user must be close to camera and there should be stable lighting conditions. These conditions restrict their applications as variation in lighting conditions, head movement, eye closure due to blinking are natural. One more problem with this approach is that thick eye glasses tend to disturb IR light which makes pupil weak. Ebisawa, proposed pupil detection based on difference method. The background is eliminated, by setting threshold value as low as possible in the difference image. They later proposed Adhoc algorithm using threshold and morphological operations to eliminate glares on the glasses. The problem with the approach; difficult to find threshold automatically, elimination of noise blobs according to their sizes is not possible and setting threshold value low is not efficient [27].

In 2000, Haro proposed pupil tracking based on appearance of eyes, dark/bright pupil effect and characteristics of motion where pupil is separated from the scene. But this method failed to detect closed/occluded eyes under different illumination conditions [36].

In 2001, Q.Ji. et.al. , proposed real time subtraction with special filter to eliminate lighting effects. But this method fails to detect closed/occluded eyes [42].

In 2004, Zhiwei Zhu & Quang Ji, proposed eye tracking method by combining appearance-based methods and active IR illumination approach. This method made use of strengths of both approaches. This method was able to handle occlusion, people with glasses but fails to detect pupil if face is completely occluded and cannot handle external illumination conditions. The conclusions drawn from this research are : (i) produce quality input images (ii) combine different complementary techniques, utilizing their strengths and overcoming limitations in order to detect pupil efficiently[62].

The traditional based methods in eye detection are further classified into three categories

i. Template Based Methods
ii. Appearance Based Methods
iii. Feature Based Methods

Facial feature extraction is one of the challenging tasks in the field of image processing and computer vision. Human Computer Interaction (HCI), face recognizer, biometric systems uses various facial features of human face. Facial feature extraction and face recognition have become very important research topics during last few decades. Among these applications driver fatigue detection system makes use of facial features such as face, eyes and mouth to detect driver fatigue.

Detection of eyes is the most important challenges faced by researchers. The problem in locating the eyes in face images is due to variety of facial expressions, head position and its background etc.,. The commonly used approaches for eye detection includes the Template Matching method (R.Brunelli,et.al.,1993 & D.J.Beymer,et.al.,1994), Eigenvectors (D.Sidibe, et.al., Muhammed Shafi,et.al., A. Pentland, et.al., 1994) method, Hough transform-based method (Jiatao Song,et.al.,2006 & R.C.Gonzalez), Support Vector Machine (SVM). Template matching employs part of the original image as template. The input images are compared with created templates, to find similarity using normal cross correlation method. The drawback of Template Matching approach is, it cannot consider variations in eye scale, facial expression, rotation and illumination. Modification in template creation yields better results.

Later Yuille,et.al., 1992, proposed eye detection using deformable templates, where eye model is translated, rotated and deformed to represent perfect eye model image. This method has an advantage of evaluating additional features in an eye like its shape and size, but success rate depends on the initial position of template. Eigen space method for face and eye detection proposed by A.Pentland et. al.,1994. If training database is variable in appearance, orientation, and illumination, then it provides better performance than template matching. However, the performance of this method depends on training set. Support Vector Machine (SVM), based

on Statistical Learning Theory (SLT) (V.Vapnik, 1995), has been widely used in eye detection (M.H.Nguyen, et.al., 2008 & H.J.Jia,et.al.,2009). The standard SVM exhibits many theoretical and practical advantages like performance, when applied to complicated large scale problems the decision function of SVM is complex, which leads to low computational efficiency and slower classification speed. Even though many solutions are suggested, the problem of eye detection is still far from its complexity.

Appearance Based Methods: These methods detect eyes based on photometric appearance. These methods need a collection of large amount of training data, representing different eye subjects, different face orientation and different illumination conditions. This data is used to train neural network or SVM. In 1994, Pentland et al., proposed eigenvectors to classify face, nose & eyes [16]. In 1997, authors proposed several improvements on neural network eye detection methods, but it was trained only for frontal images [24].

Feature Based Methods: In Feature based method, colourspace is used as a clue to segment human face and eyes. The HSV and YCbCr colourspace are used to find face and eye by eliminating background components. Eliminating the skin area, approximates eye position by removing large number of false eye candidates. The HSV provides colour information similar to as human thinks of colours. ”Hue” represents pure colour of the image and ”saturation” represents how this pure colour (hue) is diluted by white light, and ”Value” provides intensity of the colour. The first two parameters, H and S will provide discriminating information about skin region. The experimental results show that, it is difficult to know ‘Hue’ value for face segmentation and it varies from person to person. The success rate of the algorithm is 76.8% (P.Sudhakar Rao, et.al.).

Support Vector Machines (SVM) are the classifiers which distinguish between object and non-object. The first step in Appearance based technique is training of network to reject the non-eye images. Training is performed using images with features of non-eye images using Gabor filter to improve the efficiency of the method. In the algorithm, first the face is segmented using L*a*b transform colour space, later eyes are detected using HSV and Neural Network approach. The tested results show that, method fails to identify the eyes properly when face orientation. The efficiency of the method can be improved by training the SVM with more set of positive and negative images. The success rate of the algorithm is 72.5% (Vijayalaxmi, et.al.,).

Table 1: Summary of Eye Detection Techniques

Year	Method	Image Database	Total No. of images	Success Rate (%)	Improvement	Limitations
1996	Template based with optical flow	-	-	88 73(TV Movies)	Head Movement	Takes more time 2min/frame
1998	SVM	FERET	450	96	Rotated images	Wearing Glasses
2000	Contour approach	-	-	-	Stable against blinking, head translation, rotation	Takes more time
2002	Edge Segment	Local	120	90	Head Movement	Wearing Glasses
2004	SVM	Local	-	97	Works for different Illumination	Rotated images, wearing glasses
2006	Binary Template matching, SVM	BioID	23	96.8	Rotated images	Eyes Closed, Reflection
2006	Binary template matching & Hough Transform	BioID	23	95.6	Illumination	
2006	Haar Wavelets	FRGC 1.0	-	94.5	Head movement	
2008	Zernike moments & SVM	ORL	400	94.6	Head movement	Wearing glasses
2009	Deformable template matching	ORL	400	87.2	Less mathematical calculation	Wearing glasses, time consuming
2009	Morphology & Colour Image	-	-	90	Noise removal	Fails if one or both eyes are closed.1 5-20 sec on 2GHz
2010	Line edge map	Cal Tech	240	91.67	Illumination	Wearing glasses
2011	Neural Network & Hough transform	Yale,BioID,Local	304	98.68	Search time is reduced	Hough Transform needs large amount of storage & high cost in computation
2011	Neural Network, Wavelet	Olivetti research lab	75	88	Illumination, uniform background, facial expression	Complex, change in background
2011	Knowledge based Template	Face expression	200	78	Illumination	Closed eyes
2011	Skin Segmentation	Math-Works Video	126	95.2	Rotated images	Works only on one database
2012	Neural Network	GTAV	100	98	Illumination	Head rotation, background
2012	SVM & Gabor filter	GTAV, VITS	150	96	Rotation	Illumination

3. Conclusion

Eye detection methods discussed in this paper discusses various special characteristics of eyes such as eye corner, iris, eye shape, dark pupil, bright pupil, etc. to distinguish human eye from other facial features. Few techniques failed due to eye closure, orientation in face, occlusion in face, and internal and external lighting conditions. This illumination effect can be reduced using wavelet filtering, but it works for slight illumination variation.

Various colour conversion methods can be preferred to handle illumination effects but becomes costlier. Few researcher also

worked on techniques were two different approaches are combined to yield better results and also to handle special cases such as eye closure, face orientation and face occlusion, research show that combining any two methods improve the efficiency and detection rate under different conditions. The comparison of Eye Detection Techniques is summarized in Table 1.

The different eye detection techniques are compared using the fields, method, type of database, total number of images, success rate, improvement and their limitations. Few limitations of the eye detection techniques are: illumination, occlusion, face orientation, time taken to detect eyes, closed eyes, complex background. The accuracy rate of eye detection can be improved by combining two different methods but the real time implementation of eye detection has its own limitations in terms of lighting effects, face occlusion and orientation of face. The success rate of eye detection can be improved by combining two different approaches i.e., appearance based and feature based techniques.

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About Authors

First Author Dr.Vijayalaxmi completed her Doctorate from Gitam Institute of Technology, Gitam University, Vishakapatnam, Andhra Pradesh, India. She received her B.E (E&CE) degree from GNDEC, Visveswaraiah Technological University, Belgaum, and Karnataka, India in 2003. M.Tech (DE&CS) from JNT University, Hyderabad, Telangana, India in 2008. Her area of research is Digital Image Processing. She has published 25 Journal papers, 8 International Conference papers and 13 National Conference papers. She received Best Paper award in August 2013 in IEEE International conference organized by Saveetha University, Chennai, India. Also received Best Paper Award in Springer Conference ICICSE,2016 at Hyderabad. She is the Life Member of ISTE and Member of IEEE. She is Past Vice Chair of IEEE WIE AG Hyderabad Section,2015 and Present Chair of IEEE WIE AG Hyderabad Section,2016-17. Received a research project "Development of Non-Intrusive Driver Fatigue Detection & Warning System to avoid on road Accidents" sanctioned under Early Career Research Award sponsored by Science & Engineering Research Board ,Govt. of India ,New Delhi.