DRIVER’S FATIGUE DETECTION SYSTEM BASED ON FACIAL FEATURES

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I dedicate this thesis to all my friends and family, especially to my parents who supported and guided me. And to all humans who are unable to meet basic necessities of life. (May Allah bless me the strength to help them)

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"Glory be to you, we have no knowledge except what you have taught us.
Verily, it is you, the All-Knower, the All-Wise."

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ABSTRACT

With increasing number of vehicles on roads the risk of getting involved in an accident is increasing as well. In Malaysia alone, the number of traffic accidents in 2007 almost doubled as compared to the number of traffic accidents that occurred in 1997. This high accident rate has led to road accidents being the 5th leading cause of death in Malaysia and caused 9.3 billion ringgit of losses to the country in the year 2003. According to NHTSA (National Highway Traffic System Administration) reports one of the major reasons of road side accidents is fatigue while driving. Therefore, to prevent road side accidents that occurs due to fatigued drivers, it is essential to have an assistive system inside vehicle that monitors the vigilance level of driver and alert the driver in case of fatigue detection. This thesis presents a fatigue detection system based on yawning and eyes status that continuously analyse the face and facial features of the driver. Vision based approach is adopted to detect fatigue because other developed approaches are either intrusive (physical approach) that makes the driver uncomfortable or less sensitive (vehicle based approach). This system has improved the accuracy of fatigue detection by contributing in 3 steps of fatigue detection process. First step is face detection for which combination of Viola Jones and skin color pixels detection is used. Second is accurate detection of eyes and mouth in detected face area. The system uses knowledge based division and Viola Jones technique for second step. The third step is the introduction of dynamic threshold value, to check weather driver is in yawning or sleeping state. The accuracy of the system to detect fatigue level of driver is 98 % and average processing time per frame is 0.0948 seconds. The simulation results show that this system is able to detect fatigue even if driver is wearing spectacles or having beard. The algorithm is developed in MATLAB software.

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LIST OF SYMBOLS AND ABBREVIATIONS

p	-	Polarity
f	-	Applied feature
x	-	Sub window
θ	-	Threshold
η	-	Constant
h	-	Height of mouth
w	-	Width of mouth
Cb	-	Blue chrominance component in YCBCr color space
CCD	-	Charged coupled device
CLOSNO	-	Eye closure rate
Cr	-	Red chrominance component in YCBCr color space
$DOOm$	-	Degree of mouth openness
DWT	-	Discrete wavelet transform
ECG	-	Electrocardiography
EEG	-	Electroencephalography
EMG	-	Electromyography
EOG	-	Electrooculography
ELDC	-	Eyelid distance changes
FCM	-	Fuzzy c-means
HF	-	High frequency
HP_{LO}	-	Horizontal projection of open eyes
HP_i	-	Horizontal projection of frame i
HRV	-	Heart rate variability
KSS	-	Karolinska Sleepiness Scale
LF	-	Low frequency
MTO	-	Minister of transportation

NHTSA	-	National Highway Traffic Safety Administration
NTSB	-	National Safety Traffics Board
NREM	-	Non-rapid eye movement sleeps
PERCLOS	-	Percentage of eyelid closure over the pupil over time
REM	-	Rapid eye movement sleeps
RFID	-	Radio-frequency identification
SDLP	-	Standard Deviation of Lane Position
SSIM	-	Structural Similarity Measure
SVM	-	Support vector machine
SWM	-	Steering wheel movement
VGA	-	Video Graphics Array/Adaptor
VLP	-	Variation of lane position

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LIST OF PUBLICATIONS

Journals:

(i) Ijaz Khan, Hadi Abdullah, Mohd Shamian Bin Zainal (2013) "Efficient fatigue detection system as road safety feature for vehicle Research Journal of Applied Sciences, Engineering and Technology . © Maxwell Scientific Organization.

(ii) Ijaz Khan, Hadi Abdullah, Mohd Shamian Bin Zainal (2013) "Efficient eyes and mouth detection algorithm using combination of Viola Jones and skin color pixel detection." International Journal of Engineering and Applied Sciences, EAAS, Vol 3, No. 3, (2013).

(iii) Ijaz Khan, Hadi Abdullah, Mohd Shamian Bin Zainal (2013) "A Robust Hybrid Design for Driver Fatigue Detection", Journal of Information and Communication Technologies, Vol. 3, No. 4, April (2013).

Proceedings:

(i) Ijaz Khan, Hadi Abdullah, Mohd Shamian Bin Zainal "Efficient fatigue detection system as road safety feature for vehicle" Malaysian Technical Universities Conference on Engineering & Technology (MUCET 2013), 2-4 December 2013, Kuantan, Malaysia.

(ii) Ijaz Khan, Hadi Abdullah, Mohd Shamian Bin Zainal "Non intrusive alerting system for drowsy drivers", Prosiding Seminar Kebangsaan Aplikasi Sains dan Matematik 2013 (SKASM2013) Batu Pahat, Johor, 29 – 30 October 2013.

(iii) Ijaz khan, Hadi Abdullah , Mohd Shamian Bin Zainal "Vision based composite approach for lethargy detection" Signal Processing & its Applications (CSPA), 2014 IEEE 10th International Colloquium on 7-9 March (2014).

CHAPTER 1

INTRODUCTION

1.1 Overview

Driving in fatigue has long been acknowledged to be one of the main hazards in safe driving. Fatigue has a negative impact on driver's abilities of driving and impairs driver's judgment and quick response time.National Highway Traffic Safety Administration (NHTSA) analysis data indicates that driving while drowsy is a contributing factor to 22 to 24% of car crashes, and that driving while drowsy results in a four to six times higher crash risk relative to alert driver (Lee, 2008). According to the National Sleep Foundation's 2005 sleep in America poll, 60% of adult drivers – about 168 million people – say they have driven a vehicle while feeling drowsy in the past year, and more than one-third, (37% or 103 million people), have actually fallen asleep at the wheel. In fact, of those who have nodded off, 13% say they have done so at least once a month. Four percent – approximately eleven million drivers – admit they have had an accident or near accident because they dozed off or were too tired to drive (Facts, 2005).

Drowsy driving denotes a situation when the driver is in a state of mental and physical fatigue, which includes decreasing mental alertness and a sensation of weariness and reduction in eye scanning behaviours (Klauer *et al.*, 2006). A severely drowsy driver will exhibit extended incompetence to safely perform a driving manoeuvre, be unaware of the vehicle's turning radius, perform driving manoeuvres under the incorrect assumption that it is safe, experience eye lid closures and have difficulties keeping his/her head in a lifted position, minimal body/eye movement and repeated yawning(Lee, 2008). When the driver is impaired by fatigue, his/her ability levels, driving behaviours, proficiencies and decisions are adversely affected and in these situations, the high accident rate is due to the fact that sleepy drivers fail to take correct actions prior to a collision (Tun *et al.*, 2010) .

An important irony in driver's fatigue is that the drivers may be too tired to realize their own level of vigilance. This serious problem is often ignored by the driver. Driving in fatigue not only affects those who are driving while drowsy, but it puts all other road users in danger as well. Therefore, it is important to use new technologies to design systems, which are able to monitor driver's level of vigilance through the whole driving process. Fortunately, people in fatigue exhibit many visual clues that can be detected on human face e.g.

(i) Yawning
(ii) Eye blinking frequency
(iii) Eye gaze moments
(iv) Head movements
(v) Facial expressions

Taking advantage of these visual characteristics, computer vision is the viable and felicitous technology to deal with this problem. This research presents a fatigue detection system that detects fatigue by analyzing the status of driver's eyes and yawning. The aim of this project is to develop algorithm and simulation for fatigue detection. The focus will be placed on designing such algorithm and simulation that will accurately monitor eyes and yawning status of driver and will alert (written warning in case of simulation) the driver in case of fatigue detection.

1.2 Motivation

Driving is a common activity in people's everyday life therefore; improving driving to reduce car crashes is an important issue. Even though a lot of studies and work has been done on road and vehicle designs to improve driver's safety yet the total number of car crashes is increasing day by day. Reducing the number of car crashes would save millions of lives around the world every year. Most of crashes occur due to impairment of the driver's attention. Four major causes of attention impairments that affect driver's response time and alertness are alcohol, aging, distraction and fatigue. Alcohol and age factor results in slower response to hazards. Easy access of internet on cell phones and navigation systems increase driver's distraction .Out of the four major causes of driver's attention impairments, fatigue is often cited in accidents since drivers tend to adopt risky strategies to drive while drowsy(Lee, 2008). The National Highway Traffic Safety Administration has reported that driving in fatigue is one of the major reasons behind road accidents, and it exposes the driver to a much higher crash risk compared to alert drivers(Klauer *et al.*, 2006). According to MTO Driver's Handbook, driver's abilities are affected by fatigue long before they notice that they are getting tired(MTO, 2013). Therefore the need of designing and implementing an assistive monitoring system to detect driver's fatigue and to alert the driver after fatigue detection is realised that can give better performance than existing systems.

1.3 Problem statement

Researchers have been developing many methods for driver's fatigue detection using computer vision techniques. In these researches fatigue was detected by analyzing head movements, eyelid blinking and yawning. Limitation of these algorithms is that, they are dependent on one factor only (yawning or eye blink or head movement). Although some researchers used combination of two factors to improve the accuracy, however with the increasing rate of cars and car's accidents in every day's life, it is important to adjust, develop and validate the existing work for fatigue detection. This research provides an algorithm and simulation that combine two factors (yawning and eyes status detection) for fatigue detection. Combination of Viola Jones and Skin color pixel detection is used for face detection to increase the accuracy of face detection. Furthermore, combination of knowledge based division and Viola Jones method are used to increase the accuracy of facial features.

1.4 Objectives of the study

The objectives of this project are

(i) Developing algorithm and simulation for face and facial feature detection.

(ii) Developing algorithm and simulation for yawning and closed eyes status detection.

(iii) Developing algorithm and simulation for fatigue detection using information and results obtained in objective (ii).

1.5 Scope of the study

The scopes that need to be proposed in this project are:

(i) The image can be processed accurately in day light only.

(ii) Since fatigue level will be detected from facial expressions, hence user must face towards the camera.

(iii) The project will detect the fatigue level of user on software bases only.

(iv) Even if one factor (eye) is covered by spectacles, the system will be able to detect fatigue from the other uncover factor (mouth).

(v) Facial features (eyes and mouth) must not be covered simultaneously.

(vi) The project might give different results if the driver is suffering from illness.

1.6 Significance of the study

Fatigue or drowsiness often affects a person's ability of driving and increase the risk of road side accidents. The national Safety Traffics Board (NTSB) concluded that 52 % of 107 single-vehicle accidents were fatigue related; in nearly 18% of the cases, the driver admitted to falling asleep(Esre, 2009). With increasing number of vehicles on roads the risk of getting involved in an accident is increasing as well. In Malaysia alone, the number of traffic accidents in 2007 almost doubled as compared to the number of traffic accidents that occurred in 1997. This high accident rate has led to road accidents being the 5th leading cause of death in Malaysia and caused 9.3 billion ringgit of losses to the country in the year 2003(Statistics., 2008),(Mani *et al.*, 2003). Figure 1.1 shows the rate of occurrence of accidents between 2001 and 2010 and Figure 1.2 shows the increasing number of road side accidents from 1974 to 2004.

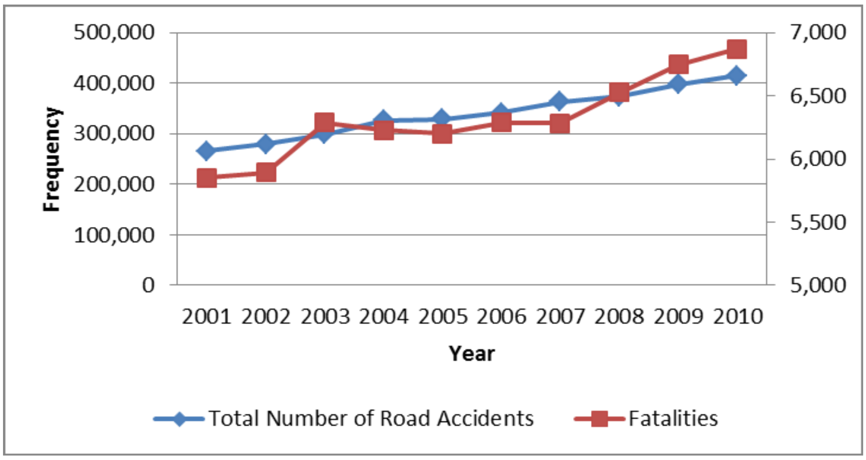

Figure 1.1: Accident Records in Malaysia from 2001 to 2010.

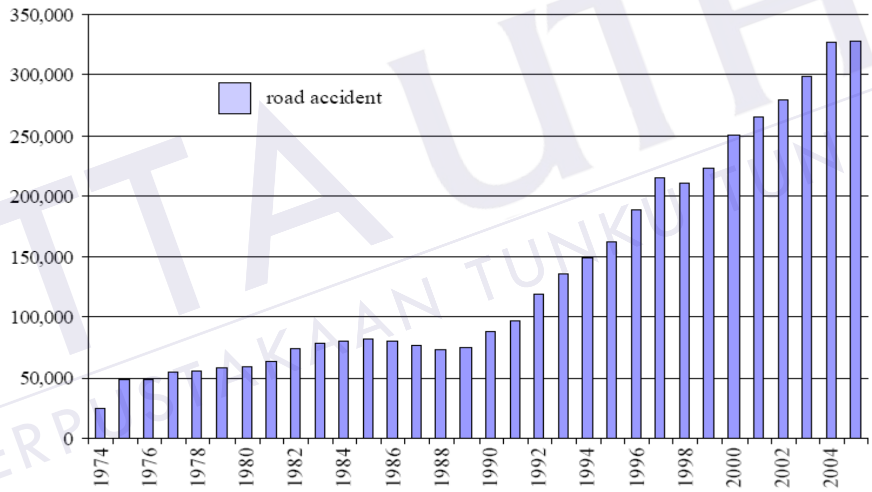

Figure 1.2: Statistics road accidents in Malaysia (2005)

The number of hours spent driving has a strong correlation to the number of hours driven and the percent of crashes related to driver fatigue related accidents.(Esre, 2009).Details of this relationship is described in Figure 1.3.

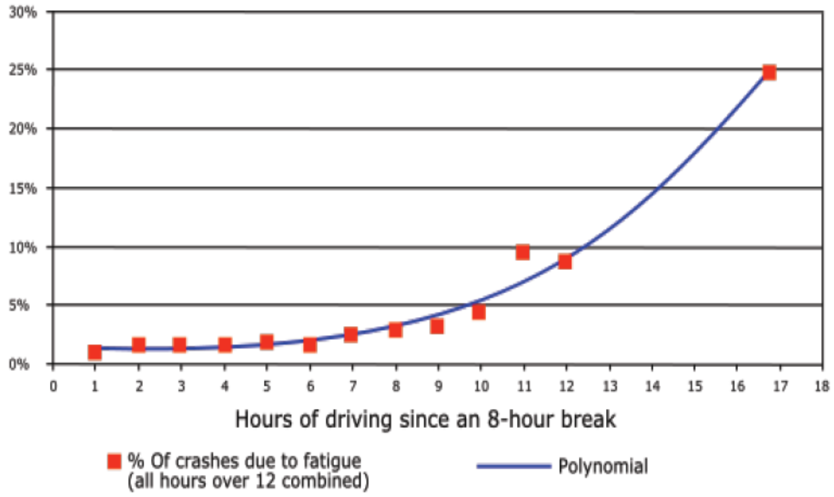

Figure 1.3: Relationship between number of hours driven and the percent of crashes related to driver fatigue

In fact, NTHSA has concluded that drowsy driving is just as dangerous as drunk driver. Therefore, it is an important issue to develop and improve the automatic fatigue detection systems that can help in saving lives and can contribute to the well being of the society.

There has been an increasing interest in computer vision approaches to prevent road side accidents as it is a prominent and non invasive approach to detect vigilance level of driver.

This project has the goal of using computer vision to detect fatigue level of driver in accurate and fast way. Many researchers have used one factor for fatigue detection but this project analyses and combines two different methods for face detection to increase the accuracy level of the system, and use two facial factors (eyes and mouth) for fatigue detection. The thesis contributes to understand how to build a robust fatigue detector based on vision without disturbance the driver’s skills.

1.7 Contribution

This research has contribution in three section of driving behavior fatigue detection system which improves the accuracy of the system to 98% and reduces the average processing time per frame to 0.09488 seconds.

(i) In first section face detection is improved by using combination of skin colour pixel detection and Viola Jones technique.

(ii) In second section facial features (eyes and mouth) detection is improved using combination of knowledge based division and Viola Jones technique.

(iii) In third section a dynamic threshold value is introduced which improves yawing detection and closed eyes status detection.

1.8 Project schedule

The project schedule is given in Appendix A.

1.9 Outline of the thesis

This thesis presents the design and evaluation of the driver monitoring system to detect vigilance level of driver. It reviews existing fatigue detection approaches, propose a robust method for fatigue detection and finally presents a set of results and associated evaluations. The structure of the thesis is as following

CHAPTER 2 LITERATURE REVIEW:

Discus the existing approaches and methods of driver monitoring systems with detail.

CHAPTER 3 RESEARCH METHODOLOGY:

Describe the detail about proposed method of fatigue detection in MATLAB and its implementation.

CHAPTER 4 SIMULATION RESULTS AND ANALYSIS:

Presents the evolution results of simulation of proposed system and analyse its performance.

CHATPTER 5 CONCLUSION AND FUTURE WORK:

Summarizes and concludes the thesis and give an outline for future work.

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