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College of Science
Department of Computer
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An Expert System for Driver's Drowsiness Detection

A Thesis

Submitted to the Department of Computer Science\ College of Sciences\ University of Diyala in a Partial Fulfillment of the Requirements for the Degree of Master in Computer Science

By

Ali Amer Hayawi

Supervised by

Assist. Prof. Dr. Jumana Waleed

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

﴿ نَرۡفَعُ دَرَجَٰتٖ مَّن نَّشَآءُۗ وَفَوۡقَ كُلِّ ذِي عِلۡمٍ عَلِيمٞ ﴾

صَدَقَ ٱللَّهُ العَظِيم

سورة يوسف

الآية (٧٦)

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ALI AMER

Supervisor's Certification

I certify that this thesis entitled **"An Expert System for Driver's Drowsiness Detection"** *was prepared under my supervision at Department of Computer Science\ College of Sciences\ University of Diyala in a partial fulfillment of the requirements for the degree of Master of Science in Computer Science.*

Signature :

Name : **Assist. Prof. Dr. Jumana Waleed**

Date : / /

(Supervisor)

Approved by University of Diyala, Faculty of Science, Department of Computer Science

Signature :

Name : **Assist. Prof. Dr. Taha Mohammed Hasan**

Date : / /

(Head of Computer Science Department)

Examination Committee Certification

We certify that we have read the thesis entitled ***"An Expert System for Driver's Drowsiness Detection"*** *and as examination committee, examined the student* ***"Ali Amer Hayawi"*** *in the thesis content and that in our opinion, it is adequate as fulfill the requirement for the Degree of Master in Computer Science at the Computer Science Department, University of Diyala.*

Signature:
Name: **Prof. Dr. Jamila Harbi Suad** (Chairman)
Date:

Signature:
Name: **Assist. Prof. Dr. Taha Mohammed Hasan** (Member)
Date:

Signature:
Name: **Assist. Prof. Dr. Ahmed Hussain Radi** (Member)
Date:

Signature:
Name: **Assist. Prof. Dr. Jumana Waleed** (Supervisor)
Date:

Approved by the Dean of College Science, University of Diyala
(The Dean)

Signature:
Name: **Prof. Dr. Tahseen Hussein Mubarak**
Date:

Linguistic Certification

This is to certify that this thesis entitled ***"An Expert System for Driver's Drowsiness Detection"*** *was prepared under my linguistic supervision. It was amended to meet the style of English language.*

Signature :

Name : **Assist prof Sundos Talib Hassan**

Date : **/ /**

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Signature :

Name : **Assist. Prof. Dr. Amal Hussein Abbas**

Date : / /

Abstract

One of the reasons for road accidents is the driver's drowsiness which leads to a considerable number of car crashes, injuries, lots of fatalities, and significant economic losses. Driver's drowsiness is represented as a state which varies between sleep and wakefulness, that decreases cognitive skills and impacts the capability of performing the task of driving. This serious issue needs to develop an effective vigilance monitoring system capable of decreasing accidents by alerting the driver under various bad driving situations. For detecting drowsiness, vehicle-based methods (such as estimating the level of drowsiness depending on the movements of the steering wheel), behavioral-based methods (detecting the driver visual features using various resources such as facial expressions, eye movements, head movements, etc.), and physiologic-based methods (detecting the earlier stages of driver's drowsiness depending on physiological signals) can be utilized.

This thesis is focused on the designing and implementation of a driver assistance system which includes a driver's monitoring and alarming by using behavioral-based method (eye movements detection method) and physiologic-based method (intrusive acquisition method, called Electrooculography (EOG) signals). In the method of detecting eye movements (Closed/Opened), the Local Binary Pattern (LBP) is used in which the descriptors are utilized to represent eye images to extract the tissue features of different persons in the driving car to see if the driver is in a drowsy state or not and this occurs after recording the driver's video and detection the eye of the driver. To extract the features in this way the image of the eyes is divided into small regions through the LBP and sequenced into a single feature vector, where this method is used to determine the similarity features in the training group and to classify the eye image. While in the used physiologic-based method, an embedded system based on ATmega2560

microcontroller on the Arduino board has been used to implement the EOG signal acquisition circuit. The developed system used several measurements to extract the features from EOG signals which makes it very sensitive to detect the driver's drowsiness. Furthermore, K Nearest Neighbors classifier (KNN) and Support Vector Machine (SVM) are used to give good accuracy. This system creates a low-cost device capable of quickly alerting the driver to ensure their safety. The experimental results show the efficiency and reliability of the proposed driver assistance system. The results indicate that the system has a high accuracy rate comparing with the other existing methods where the accuracy rate of KNN and SVM using EOG signal dataset (90% training and 10% testing) are 95% and 99.9% respectively, and the accuracy rate of KNN and SVM using eye detection dataset (90% training and 10% testing) are 98% and 100% respectively.

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List of Abbreviations

Abbreviation	Description
ECG	Electrocardiogram
EEG	Electroencephalogram
EMD	Empirical Mode Decomposition
EMG	Electromyography
EOG	Electrooculogram
SWM	Steering Wheel Movement
SDLP	Standard Deviation Of Lane Position
SD	Standard Definition
HD	High Definition
RGB	Red/Green/Blue
IDE	Integrated Development Environment
LBP	Local Binary Pattern
SVM	Support Vector Machine
KNN	K Nearest Neighbors

Chapter One

General Introduction

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

At daily life, driving is a significant activity and with the passage of time, the number of vehicles is continued to increase leading to increasing road accidents. These accidents produce a state of disquiet to the individuals over the world, affect the main life component which is the human, and exhaust the material resources. Therefore, the proposals and solutions should be found to decrease the traffic accidents or at least determine the reasons and decrease the passive-effects and identify the core issues that lead to the traffic accidents occurrence, such as driver’s drowsiness, road problems, vehicle breakdown, and etc. [1].

Regarding the government information released via the Statistics Central Bureau of the Ministry of Planning, the government of Iraq witnessed after "2003" a considerable increase in the number of vehicles reach to 5.8 million vehicles distributed among the provinces. Within the past ten years, more than sixty-six thousand traffic accidents have occurred in Iraq conducting 22,952 of dead people and 79545 of injured people. The Report on traffic accidents released via the Statistics Central Bureau presented that the collisions registered the highest ratio through the year "2015" [2]. Figure (1.1) shows the ratios for different types of traffic accidents for the year "2015", and also illustrates the high ratio of accidents is occurred by the drivers [3].

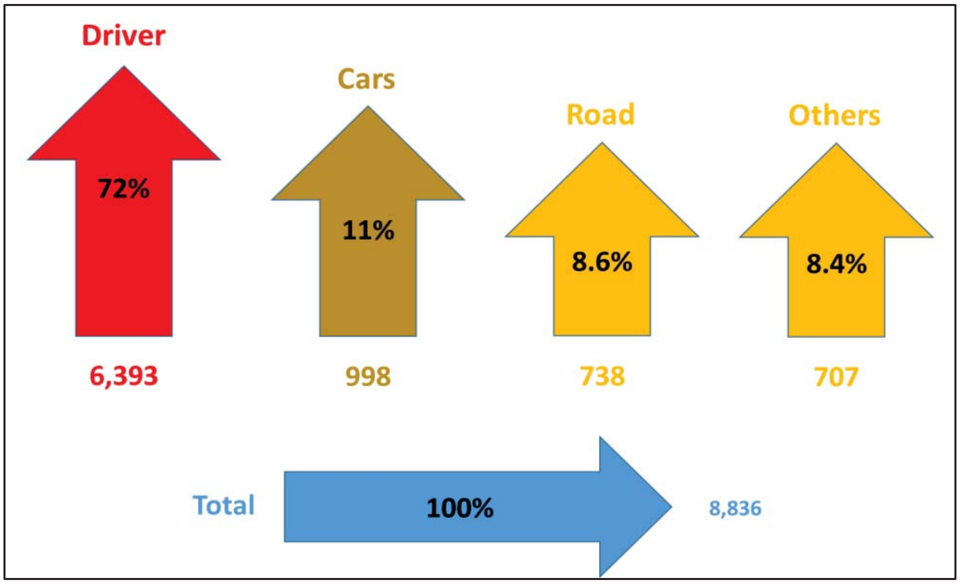
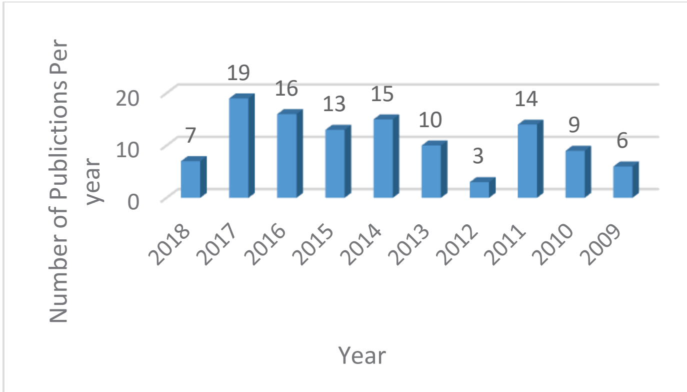


Figure (1.1): The ratios for different types of traffic accidents [3].

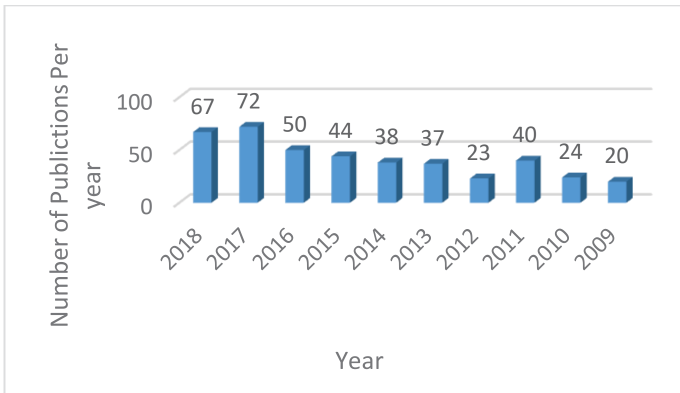
Drowsiness indicates to the near sleeping, an intense willing for sleeping, or sleeping of unusual long times. The persons in a particular status like driving a car should stay alert. On the contrary, dangerous accidents may happen [4]. In order to avoid these accidents, driver assistance systems are required which are capable of detecting driver drowsiness and sending an alert.

1.2 Related Works

Considerable researchers have exhausted a lot of effort in studying the driver's features in particular situations to design systems capable of detecting typical drowsiness signs. Figure (1.2) demonstrates the number of publications in the area of driver drowsiness detection system at the websites of "IEEE Explore", and "Science Direct" for the last ten years [3].



(a)



(b)

Figure (1.2): The publications distribution data for the years 2009-2018 have been retrieved from the websites (a) "IEEE Explore"; (b) "Science Direct" [3].

Regarding the physiological measures, the systems utilized in data gaining to detect sleep stage are depending on the generation of the signals of the electrocardiogram (ECG), the electrooculogram (EOG), the electromyography (EMG), and the electroencephalogram (EEG). It is very difficult to perform a device that alerts the drivers when falling asleep utilizing EMG and EEG signals due to a large number of electrodes that have to be located on the driver's skin [5]. EOG is the most commonly utilized physiological signal in automatic detection of sleep stages.

Hu Shuyan and Zheng Gangtie, 2009 [6] presented to perform the drowsiness prediction by employing Support Vector Machine (SVM) with eyelid related parameters extracted from EOG data collected in a driving simulator provided by EU Project SENSATION. The dataset is firstly divided into three incremental drowsiness levels, and then a paired t-test is done to identify how the parameters are associated with drivers' sleepy condition. With all the features, a SVM drowsiness detection model is constructed. The validation results show that up to 86.67% of the trials accurately detect when the subject is 'sleepy'. 16.67% of the trials which are supposed to be 'alert' are wrongly detected as 'sleepy'/ 'very sleepy'.

Mandalapu Sarada Devi et al., 2011 [7] presented a vision-based real-time driver drowsiness detection system for safety driving. The system localizes and tracks the eyes of a driver in order to detect drowsiness. Skin color model is used for face detection and after that eyes are detected by using Circular Hough transform, and then eye state is estimated (whether opened or closed) by using developed distance logic. This designed system detected face as well as eyes with an accuracy of 80%. Sometimes because of dark background the system may not be able to detect the face hence system produce some error in eye detection and gives false alarm of fatigue detection. During tracking, the system is able to decide if the eyes are open or closed. When the eyes have been closed too long, drowsiness is detected and warning signal is issued.

Wei Zhang et al., 2012 [8] presented a nonintrusive drowsiness recognition method using eye-tracking and image processing. A robust eye detection algorithm is introduced to address the problems caused by changes in illumination and driver posture. Six measures are calculated with the percentage of eyelid closure, maximum closure duration, blink frequency, the average opening level of the eyes, opening velocity of the eyes, and closing velocity of the eyes. These measures are combined using Fisher's linear discriminant functions using a stepwise method to reduce the correlations and extract an independent index. Results with six participants in driving simulator experiments demonstrate the feasibility of this video-based drowsiness recognition method that provided 86% accuracy.

Nantakrit Yodpijit et al., 2015 [9] proposed a low-cost blinking detection system is built with simple modules and acceptable performance by measuring the EOG signal from one low-pass filter. Results from the preliminary experiments suggest that the blinking detection system can work just fine under controlled conditions such as in a laboratory. However, this blinking detection system has some technical issues that need to be resolved such as; an automatic blinking detection system, the instability of the signal, the use of electrodes, etc. There are several limitations to using this blinking detection system. Examples are; firstly, the decision parameter needs to be adjusted by the users, secondly, the electrode wires are no longer needed for the further development of the blinking detection system. In this system, the accuracy rate has not been computed, also, there are several points that should be provided, like installing this system in a driving simulator and/or a real vehicle, and testing as an in-vehicle warning system to protect drowsy drivers.

Zheren Ma et al., 2016 [10] presented a wearable drowsiness detection system. This system measures the EOG signal; transmits the signal to a smartphone wirelessly, and could alarm the driver based on a prediction algorithm that can estimate 0.5-second-ahead EOG signal behavior. This system is compact, comfortable, and cost-effective. The 0.5-second ahead estimation capability provides the critical time for a driver to correct the behavior and ultimately saves lives. In this system, the accuracy rate has not been computed.

Jinan Deeb et al. 2017 [11] proposed an empirical mode decomposition (EMD) method as a signal decomposition tool. This kind of method is useful for the analysis of natural and non-stationary processes. Some parameters are calculated for each intrinsic mode function. EMD is proved to be adaptive and highly efficient in the analysis of such signals and the proposed parameters provided significant differences between normal and sleepy status and developed an algorithm enabling reliable analyses of routine EOG measurements. Generally, the algorithm offered a successful option to attain knowledge of human sleepiness and fatigue. As perspective, the results could be used for the implementation of a real drowsiness detection system. This system should work on merging hardware and software, miniaturization, and installation on a person during driving.

Rateb Jabbar et al., 2018 [12] presents an approach towards real-time drowsiness detection. This approach is based on a deep learning method that can be implemented on Android applications with high accuracy. The main contribution of this work is the compression of the heavy baseline model to a lightweight model. Moreover, the minimal network structure is designed based on facial landmark key point detection to recognize whether the driver is drowsy. According to the experimental results, the size of the used model is small while having an accuracy rate of 81%.

Shaibal Barua et al., 2019 [13] proposed an automatic sleepiness classification scheme designed using data from 30 drivers who repeatedly drove in a high-fidelity driving simulator, both in alert and in sleep-deprived conditions. Driver sleepiness classification was performed using four separate classifiers: k-nearest neighbours (KNN), support vector machines (SVM), case-based reasoning, and random forest, where physiological signals and contextual information based on electroencephalography (EEG) and EOG electrodes were used as sleepiness indicators. The subjective Karolinska sleepiness scale (KSS) was used as a target value. An extensive evaluation of multiclass and binary classifications was carried out using 10-fold cross-validation and leave-one-out validation. With 10-fold cross-validation, the SVM (when 80% training and 20% testing) showed better performance than the other classifiers (79% accuracy for multiclass and 93% accuracy for binary classification).

Ameen Aliu Bamidele et al. 2019 [14] proposed a behavioral driver drowsiness detection system based on tracking the face and eye state of the driver. In this system, the National Tsing Hua University (NTHU) Computer Vision Lab's driver drowsiness detection video dataset was utilized. Several video and image processing operations were performed on the videos so as to detect the drivers' eye state. From the eye states, three important drowsiness features were extracted: percentage of eyelid closure, blink frequency, and maximum closure duration of the eyes. These features were then fed as inputs into several machine learning models for drowsiness classification. Models from KNN, SVM, Logistic Regression, and Artificial Neural Networks (ANN) machine learning algorithms have experimented. The obtained result shows that the best models were a KNN model when k = 31 and an ANN model that used an Adadelta optimizer with 3 hidden layer network. The KNN model obtained an accuracy of 72.25%, while the ANN model obtained an accuracy of 71.61%.

1.3 Problem Statement

In recent years, various systems for developing effective driver assistance systems have been proposed. Most of these systems are depending on physiological measures and the main advantage of these measures is that the physiological signals begin to alteration in earlier stages of drowsiness, that provide the earlier detection for the driver's drowsiness with maximum accuracy. While, the main disadvantage of these measures is that the physiological signals are commonly gained utilizing intrusive approaches and though several methods have been found to gain these signals utilizing non-intrusive approaches, losing the quality of signals is yet considerable [15]. Also, these systems may depend on behavioral measures used to detect the visual features of drivers utilizing a camera. Visual features sources involve eye movements, facial expressions, and head movements. The main advantage of these visual-based systems is that they can be obtained non-intrusively. But, the conditions of sunlight and light may make the task complicated. Additionally, with the partially automated driving, potentially the drivers look away from the road, and that required extra cameras or a bigger head box for providing accurate imagery to the face [16]. In this thesis, a driver assistance system is designed and implemented which includes a driver's monitoring and alarming by using intrusive and non-intrusive acquisition methods.

1.4 Aim of Thesis

The aim of this thesis is to create an accurate and low-cost system capable of quickly alerting the drivers from the drossiness to ensure their safety. The developed system is based on utilizing two methods; behavioral based method (detecting the driver visual features using eye movements (closed or opened)), and physiological based method (detecting the earlier stages of driver's drowsiness depending on EOG signals).

1.5 Outlines of Thesis

In additional to chapter one, this thesis contains four chapters:

Chapter Two: Theoretical Background

This chapter gives the background and review of some techniques especially the techniques based EOG and the techniques based detecting the driver visual features using eye movements، local binary pattern, Viola-Jones, and machine learning.

Chapter Three: The proposed system

This chapter describes the proposed system with their design and implementations.

Chapter Four: Experimental Results and Discussion

This chapter explains the results that have been gotten from the proposed system.

Chapter Five: Conclusion and Suggestion for Future works

This chapter covers the conclusions observed from the system, and the applications in which the system can may be also used for. Finally, the future work is recommended for the proposed system.