Non-Intrusive Drowsiness Detection System

Design, analysis and evaluation of Non-Intrusive Driver Drowsiness System using a Support Vector Machine and Fault Diagnosis System

Ashardi bin Abas

Submitted for the Degree of
Doctor of Philosophy

Department of Computing
University of Bradford

2011

Abstract.

The development of technologies for preventing drowsiness at the wheel is a major challenge in the field of accident avoidance systems. Preventing drowsiness during driving requires a method for accurately detecting a decline in driver alertness and a method for alerting and refreshing the driver. As a detection method, the authors have developed a system that uses image processing technology to analyse images of the road lane with a video camera integrated with steering wheel angle data collection from a car simulation system. The main contribution of this study is a novel algorithm for drowsiness detection and tracking, which is based on the incorporation of information from a road vision system and vehicle performance parameters. Refinement of the algorithm is more precisely detected the level of drowsiness by the implementation of a support vector machine classification for robust and accurate drowsiness warning system. The Support Vector Machine (SVM) classification technique diminished drowsiness level by using non intrusive systems, using standard equipment sensors, aim to reduce these road accidents caused by drowsiness drivers. This detection system provides a non-contact technique for judging various levels of driver alertness and facilitates early detection of a decline in alertness during driving. The presented results are based on a selection of drowsiness database, which covers almost 60 hours of driving data collection measurements. All the parameters extracted from vehicle parameter data are collected in a driving simulator. With all the features from a real vehicle, a SVM drowsiness detection model is constructed. After several improvements, the classification results showed a very good indication of drowsiness by using those systems.

Acknowledgements

First of all, I thank Allah for his unlimited grade and help to complete this thesis. I would like to express my deep thanks and appreciation to my parents who bought me up and make me realize the importance of education.

I deeply thank my wife and daughter for the support and sacrifices they make for me and everything they have done in order to provide a quiet and peaceful environment.

I would also like to extend my appreciation to Mr John Mellor & Dr Ping Jiang for their assistance in educating, assisting and helping me on the preparation of this thesis. I am grateful to him for accepting me as research student and for being patient with me during my stay at University of Bradford. Finally, I am grateful to my parents for their encouragement and support. Last but not least, my very deep gratitude and thanks to my wife, Farahida Isa for her patience and sacrifice and also to my children Safiya for theirs patience and understanding.

Table of Contents

Contents

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

List of Figures

List of Tables

Chapter 1

Introduction

The following introduction provides a background to the PhD thesis dissertation which is the basis of the research interest. The motivation, research aims and objectives will be laid out to give the reader a glimpse of what is the inspiration for the work.

1.1 Background to driver drowsiness

Using transportation is an everyday practice, a characteristic of the modern world, but the human role is basically taken for granted. People are using different transportation modes such as cars, buses, trains, ships or aircrafts. From all these modes of transportation road traffic injuries is consistently one of the top three causes of death for people aged between 5 to 44 years old. More than 1.2 million people die on the world's roads every year, and as many as 50 million others are injured [4].

When people drive while they are tired, drowsy or sleepy, this is commonly referred to as "driver fatigue" or drowsy driving. Drowsiness in driving is believed to cause an increasing number of accidents on the roads. "Official" figures claim that driver drowsiness is estimated to cause 1-3 % of the traffic accidents, but an actual number is generally considered to be much higher. Drowsiness is the transition state between being awake and being asleep during which a decrease of vigilance is generally observed. This can be a serious problem for tasks that need sustained attention, such as driving.

Driver drowsiness is a significant factor in the increasing number of accidents on today's roads and has been extensively accepted [7]. This evidence has been confirmed by many researchers that have formed connections between drowsiness and road accidents. Even though it is hard to decide the accurate number of accidents due to drowsiness, it is likely to be underestimated because of the difficulty to distinguish from those caused by other factors like alcohol or drugs.

Research based in the UK shows that drowsiness is one of the greatest causes of road accidents, totalling up to 20% of serious accidents on motorways and rural roads in Great Britain [58]. The Government has identified driver drowsiness as one of the main areas of a driver behaviour that needs to be addressed. The above statement shows the significance of any research with the objective of reducing the dangers of accidents accredited to drowsiness.

So far, researchers have tried to model the behaviour by discovering relationships between drowsiness and certain indications that linked the vehicle with the driver behaviour [7], [8], [9]. We will explore this in more details to help clarify the problem.

Time is nowadays expressed in 24 hours operation, and more and more people are conducting vigilance-based activities at any time other than the traditional daytime working hours. Starting at the end of the last century, night-time has become an opportunity for production, and there is evidence that these tendencies will increase [10]. The numbers of accidents caused by drowsiness are increasing due to the tendency that sleep is being less prioritized; hence, more people are sleep deprived. Commercial drivers are no exception. Tight schedules and time pressure make drivers drive for longer hours and during night time to avoid traffic. Individual differences on how to handle sleepiness and to which extent it affects performance exists, but they are limited. There is no evidence that the need for sleep of "professionals" is different from what observed in other persons. Motivation, commitment and extra pay could only prevent sleepiness for transient periods of time. People in general tend to overestimate their own ability to handle their sleepiness. They often consider the risk of reduced performance less when it comes to their own driving, with the argument that precedent ensures an adequate safety margin (i.e. they have performed sleepy in the past and not had a catastrophe). The circadian rhythms are low in the early-morning hours as well as in the mid-afternoon.

Driving during these hours could affect performance in combination with other factors like sleep loss or driving for longer periods of time be the cause of sleepy driving, depends on the professionalism of the driver [11]. Hence, drivers are not always good judges of their own sleepiness. Even if they are aware of their sleepiness, they could be unaware of the risk of falling asleep [12].

Populations that have been known to be at higher risk for involvement in sleep-related crashes include young people, especially young males, persons with

sleeping-disorders, those who have taken soporific medications and night-time or shift workers. Commercial vehicle operators are also at increased risk for sleep-related crashes due to factors like extended driving times; irregular work and sleep schedule, higher frequency of night-time driving and inadequate sleep [12]. This opinion is also shared by Sagberg [13] who had looked at several crash statistics from different references and come to the conclusion that the problem with fatigue-related crashes seems to be higher among truck drivers than drivers in general, probably since truck drivers mainly drive on large monotonous roads and often drive during night-time. The accidents associated with sleepy driving are therefore, more often fatal since the speeds are higher on highways, main roads and motorways combined with a delayed reaction time of the driver. Dinges, David F. [10] claims from the statistics which indicate that the sleepiness-related accidents are common on long stretches of the motorway, perhaps amounting to 40 % or more of the fatal crashes. According to him, National Transportation Safety Board (NTSB) (1990) has implicated that fatigue is the most frequent contributor to crashes in which a truck driver was fatally injured. Stutts, J.C. [12] made a population-based case-control study where drivers involved in accidents in North Carolina were interviewed over the telephone. They compared a group of drivers who had been reported (by the police) to be asleep or fatigued by the time of the crash with a control group where drivers had either been in a recent crash not related to fatiguing or not in a crash at all. Results showed that drivers in the sleep-related crashes were more likely working in multiple jobs, night shifts or other irregular work schedules, more likely to have used soporific medications, had been driving for longer time and had slept fewer hours the night before. They also reported poorer quality of sleep (and averaged

less sleep per night), drove more often late at night, and had more prior instances of sleepy driving.

Dinges, David F [10] states that a low level of vigilance gives risk to a dangerous driving style in terms of steering wheel movements, lane keeping and speed variation. Other researchers [13], [14] have studied changes in steering wheel activity associated with decreased alertness. Their study showed that small magnitude steering wheel movements decreased in frequency when the driver was not sleepy. On the other hands when the driver was getting sleepier, large magnitude steering wheel movements will be increased in frequency.

This has also been identified in [11] as showing possible warning signs of a sleepy driver along with factors such as:

- No memory of the last few miles driven.
- Zigzag driving, lane drifting, hitting rumble strips, keeps jerking the vehicle back into the lane.
- Wandering or disconnected thoughts.
- Repeated yawns.
- Difficulty to keep eyes open.
- Driving too close to the vehicle in front.

Technology, particularly which monitors a driver behaviour and shares this information could play an important role in changing norms and the driving culture. A number of approaches to drowsiness detection mainly make pre-assumptions about the relevant driver behaviour, concentrate on blink rate, eye closure, and yawning [15], [16]. The automobile industry also has tried to develop various systems to predict driver drowsiness but there are only a few commercial products available today [17]. The systems do not look at driver performance and

overlook driver ability and characteristics. Naturally, most people would agree that different people drive differently. Thus, it is proposed that the system that is developed must be able to accommodate to the changes of the different driver behaviour.

In-vehicle sleepiness detection measures variables from the vehicle itself. These systems are based on the idea that a driver goes through different stages as he/she is getting sleepier. Before the sleepy stage, there is usually a period of degraded driving, which can be detected by measuring different in-vehicle variables [18]. Such a system would gather signals in real-time that are then passed through an algorithm that is trained to detect sleepy driving behaviours. If the outcome from the formulas of the algorithm is higher than the set threshold, the system should produce a warning. It is important to notice the difference between detection and prediction. A system should preferably be able to predict driver sleepiness, although this is harder to achieve. Detection of driver sleepiness could be sufficient, but it could also mean that the system discovers the sleepy driving behaviours too late, and the accident cannot be avoided.

1.2 The models

The body of research that has been accumulated on driving behaviour presents a collection of findings and conclusions from which it is possible to make a coherent picture. That picture is our theory of driving behaviour. Once we have a theory, we can continue gathering additional 'facts' to fill the remaining gaps. The purpose of the models and theories of driver behaviour is to make sense of all the research results. A theory and a model are not synonyms. A theory is a conceptual organization of concepts, mechanisms and processes that are involved in the operation of a system. A model is less presumptive in the sense that it does not presume that these mechanisms and processes actually exist, but only that if we posit them, then we can explain human behaviour. Often, a model of human behaviour is developed and then a search is made to see if some of its mechanisms actually exist.

A model can often serve as a basis for a theory. In general, unless there is independent evidence for the existence of specific processes and mechanisms, it is safer to talk on models of driver behaviour than theories of driver behaviour [6].

1.3 Drawbacks of current developments

Numerous kinds of warning systems have been developed to prevent the driver from falling asleep while driving. Some of these systems are based on body signals from the driver:

- EEG.
- Eye movements.
- Blinking rate.

To be able to receive these signals, special sensor equipment like wiring or camera is needed and that could be an obstructive or disturbance for the driver. Using camera to read signals from either eye movement or blinking rate could, except being a quite expensive method, be difficult to use in a non-heterogeneous environment where different lighting and other factors like usage of glasses complicate the gathering of information.

A system that measures in-vehicle signals:

- Steering wheel variance.
- Lateral lane position drifting.

According to [19] there are existing in-vehicle systems meant to detect driver sleepiness in commercial and non-commercial driving but the evidence to judge its application and efficiency is insufficient. In a study made [20] where behavioural adaptation of drivers to Fatigue Warning Systems (FWS) was evaluated. They concluded that their findings suggested that FWS is currently conceived may not contribute to reduce fatigue induced collisions. This implies that systems famous to today do not live up to the expectations of FWS and that further studies are needed.

1.4 Research aim and objectives

The aim of this thesis is to contribute to the study of driver behaviour, through the development and evaluation of a driver drowsiness detection system. A non-intrusive system is chosen as a preferred approaches due to comfort to the drivers as it is done by monitoring the driver's activity through the various vehicle controls such as steering wheel, accelerator and brake and the measurements from the relationship between the vehicle and its environment. A further aim of the research is to produce systems that can be capable in detecting the drowsiness level at an early stage by giving warning to drivers about their lack of attention due to drowsiness or other factors. In other words, they can correct the behaviour or stop driving when they are in drowsiness state. This system needs to be robust against the interferences and comfort constraints and particularly not false indicators, which would cause a driver to distrust and ignore the system.

Our first objective is to develop an algorithm which relies on only in-vehicle variables, for which extensive experiments need to be done to collect adequate information from real situations. This means that quantitative tests have to be performed in a driving simulator. Through these tests, proper variables could be identified to show when a driver is sleepy. The best variables should be combined to create a formula that, if shown to be effective, might be implemented in future systems.

The second objective of this research is to identify the current drowsiness detection by investigating adaptable methods in studying the relationships between driver's manoeuvre performances whiles the vehicle on the move and the physiological driver drowsiness states.

The third objective is to study on pattern recognition methods in detecting drowsiness from the collected variables.

This thesis outlines the following task for the research design and development of a system that focuses on driver's drowsiness detection and prediction through the following methods:

- Initial research to characterise the measurements available from a vehicle such as steering angle, steering angle velocity, speed, acceleration, brake and accelerator inputs. Real measurements from vehicles have been obtained.
- Development of a research test-bed simulator consisting of driver controls connected to a computer running simulated road conditions.
- Validation of simulator results with real measurements for non-drowsy and drowsy behaviour.

The main focus of the research is the development of the drowsiness detection and prediction system algorithms using the following:-

- Monitoring the driver behaviour by observing the vehicle manoeuvre stability and performance.
- Validate and measure the progress by using a specific algorithm.
- Updating the current performance by comparing with the last action stored in the system database.
- Warning the drivers if the behaviour fall outside the standard thresholds that have been set.

To increase the accuracy of detection and its reliability of the prediction, the methods mentioned earlier have been used. Here, we will employ machine

learning methods to classify the data of actual human behaviour during drowsiness.

This is done by studying and evaluating the learning phase identification of a driver's driving pattern by evaluating the parameters comprehensively. For achieving the best possible alert a control system mechanism that integrates human and machine classification using information from various sources has been used.

1.5 Research approach

The early stages of the research work were used to identify from a range of possibilities for the best approach to study the problem. Building and fitting instrumentation to a vehicle were considered and background research conducted, but such measurement systems are now being incorporated into new vehicles by manufacturers as part of the improved road holding and performance features and 'drive by wire' vehicle control systems. Any modification to a real vehicle could compromise vehicle safety and were not approved. After extensive research and evaluation, a method of study was developed and an experimental environment defined. Thus, the scope of the thesis is defined as follows:

- The evaluation of the algorithms will be restricted to the simulation environment only.
- There are no obstacles in the road lane, and thus there is no collision-avoidance aspect to manoeuvre.
- It is assumed that the vehicle will operate within a fixed velocity of 50km/h.

- Two main parameters were identified from the research as indicators for the system detection and these consist of distance to lane boundary and steering wheel angle.

1.6 Contributions

The contributions of the thesis research extend to several areas. The main contribution of this study is a novel algorithm for drowsiness detection and tracking, which is based on the incorporation of information from a road vision system and vehicle performance parameters. Refinement of the algorithm is more precisely detects the level of drowsiness by the implementation of a support vector machine classification for robust and accurate drowsiness warning system.

The adaptive system is deriving by combining data from the road vision and data logger to provide an efficient method in detecting drowsiness. It is designed to work with under several modes and with different road conditions. This is supported by experimentation using different drivers with various conditions in order to build the adaptive system. The system was further refined by the incorporation of a novel strategy which employed a fault diagnosis technique that integrates information from trained classifiers, which are used to improve the accuracy and reliability.

The postulation of a model that considers the driver as a component or part of the vehicle in a closed-loop system and the evaluation of a minimum subset of parameters that would characterise the closed loop sufficiently to allow system performance degradation to be detected.

1.7 Thesis outline

As an introduction, Chapter 1 will examine the role of fatigue and extreme sleepiness in automobile accidents, and the enormous costs (both monetary and human) associated with them. The objectives of the current study are outlined, and an overview of the thesis is presented.

Chapter 2 of this report consists of a comprehensive review of literature and existing systems for incorporating the relevant previous findings, eliminating duplication of efforts, and examining the earlier proposed detection and warning systems, with a particular emphasis on driving conditions. Factors that contribute to drowsiness, measures to counter driver fatigue/drowsiness, previous studies and surveys are discussed in details. We have attempted to provide a complete overview of existing systems and previous work.

Chapter 3 presents the first steps in order to obtain and validate certain inputs that can be used reliably toward the classification process. It describes the driving simulator laboratory setup, how the simulator was used to conduct the experiments for this project. Full details about the capabilities, working and activities performed during construction. During these experiments, drivers drove the simulator. Data was recorded for vehicle parameters related to driver driving activity. Data recorded in these experiments was used to develop and validate the detection algorithm.

Chapter 4 discusses on how distance to lane boundary data extraction technique was set and how the data being extracted. Matlab toolbox is used as a tool to extract the data from moving image and converted to meaningful data analysis.

Chapter 5 presents the support vector machine concept and implementation. The rationale and purpose of the study are reviewed, followed by a detailed description of the experimental methodology, including the data collection and analysis procedures and finally, the algorithm development and testing. It summarizes the results of this research and presents findings from the parametric study and presents the main results of this study. The results can be classified into three sections, each consisting of a description of the main findings, discussion and concluding remarks of the results.

Finally, the conclusion of the research and recommendation on future research are provided in Chapter 6, which presents the important conclusions from this study, the industrial significance of this work and provides recommendations for future work. The appendix contains a sample of the major experiment files used to perform the simulation.