Faculty of Computer Science and Information Technology

Detection of Yawning and Eye Closure for Monitoring Driver's Drowsiness

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Bachelor of Computer Science and Information Technology with Honour

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LIST OF ABBREVIATIONS

Artificial Intelligence (A.I)

Application Programming Interface (API)

Circular Hough Transform (CHT)

Electrooculography (EOG)

Electroencephalogram (EEG)

Global- Positioning System (GPS)

Multi-Layer Perceptron (MLP)

Percentage of Eye Closure (PERCLOS)

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ABSTRACT

Over the years, traffic accidents related to drowsiness has been steadily rising. There are experimental methods that relies on brain activities to determine if the driver is drowsy using special equipment such like ECG or EEG which requires extensive wiring and special equipment. Moreover, driver assisting visual display is becoming a norm in most modern vehicles where assistive information is provided to aid the driver in decision making. However, such design imposes a distraction for the driver as too much information may induce confusion to the driver when making decisions especially during emergencies. This project proposes a framework of using only mobile device and cloud services to detect drowsiness in driver and alerting them through audio feedbacks. By utilising cloud services, computational expenses for executing the image processing algorithms on the mobile device can be minimised.

At the end of this project, a mobile application prototype is implemented together with the results of experiment as a proof of concept to the proposed framework. The results of classification accuracy and facial detection ability are recorded and tabled. Based on the results, the proposed framework yield 82.22% and 96% for classification accuracy and facial detection, respectively, with appropriate audio feedback mechanism in place. Project conclusion with limitations and future work are discussed at the end of this research.

ABSTRAK

Sejak kebelakangan ini, kemalangan lalu lintas yang berkaitan dengan mengantuk semakin meningkat.Terdapat kaedah eksperimen yang bergantung kepada aktiviti otak untuk menentukan sama ada pemandu mengantuk menggunakan peralatan khas seperti EEG atau yang memerlukan pendawaian yang luas. Tambahan pula, pemandu membantu visual paparan menjadi satu norma dalam kebanyakan kenderaan moden di mana maklumat bantuan disediakan untuk membantu pemandu dalam membuat keputusan. Walau bagaimanapun, reka bentuk tersebut akan menganggu pemanduan kerana terlalu banyak maklumat boleh mendorong kekeliruan kepada pemandu apabila keputusan yang dibuat terutamanya semasa kecemasan. Projek ini mencadangkan rangka kerja menggunakan hanya peranti mudah alih seperti telefon pintar dan perkhidmatan teknologi awan untuk mengesan mengantuk dalam pemandu dan menyedarkan mereka melalui maklum balas audio. Dengan menggunakan teknologi awan, kos pengkomputan untuk melaksanakan algoritma pemprosesan imej pada peranti mudah alih boleh diminimumkan.

Pada akhir projek ini, sebuah prototaip aplikasi mudah alih dilaksanakan bersama-sama dengan hasil eksperimen sebagai bukti konsep kepada rangka kerja yang dicadangkan. Keputusan mengenai ketepatan klasifikasi dan keupayaan pengesanan wajah direkodkan dan dibentangkan. Berdasarkan keputusan, hasil kerja dicadangkan 82.22% dan 96% untuk ketepatan klasifikasi dan pengesanan wajah, masing-masing, dengan mekanisme maklum balas audio yang sesuai. Projek kesimpulan dengan batasan dan kerja masa depan dibincangkan pada akhir kajian ini.

CHAPTER 1: INTRODUCTION

1.0 Background

Fatigue and drowsiness have been identified as the main contributor to the rise in number of fatal crashes and injuries especially driving on long and monotonous roads. According to Malaysia Institute of Road Safety (MIROS), an average of 18 people is killed on our roads daily and the number is expected to increase to 29 people by year 2020. Drowsiness on the road may be due to circadian-rhythm disorders and diseases which may affect even a well-rested driver. In recent years, many researches have been studying on effective ways to monitor driver's performance with the help of current technologies and algorithms. According to Khan (2019), "a prominent objective in this field is Vision Zero, which envisions a future where no one is injured or killed in a road accident". Shall have a better way to quote this in order to connect with next sentence. Vision Zero has a broader spectrum, however, this project will focus on studies and system developed to enhance road safety and driver performance.

Apart from driving safety, drivers' comfort has become an emerging concept for modern vehicular technology. Numerous researches have been initiated to study and develop electronic system that ergonomically suited to assist drivers to minimise their distraction and help them focus on the road. For instance, the Mercedes Benz E-class has introduced Driving Assistance Package in their 2018 models which provide comfortable support for driver in steering assistance and prevent any lane deviation. However, such system relies too much on road structures which can heavily affected by weather patterns and other obstacle interference. Therefore, assistive-steering feature based on road patterns and structures has its vulnerabilities.

Over the decades the use of percentage of eye closure (PERCLOS) metric as an evaluation standard for detection of fatigue drivers within a finite period is persistent. When a person becomes drowsy, there is a reduction in inputs to the thalamic motor projections to the face, including the eyelids, causing these muscles to relax, resulting in increasingly longer periods of eyelid closure (Culebras, 2002). Using such prolonged eyelid closure period, the percentage of difference between the upper and lower eyelid can be computed to define if the driver is drowsy. The limitation of using PERCLOS is determining the threshold level of drowsiness as there are huge variation between individuals. Some drivers have better tolerance to drowsiness and are able drive while some would just enter light sleep stage.

Apart from eye detection, yawning is also a sign of fatigue which leads to drowsiness. A study suggests that frequent yawning followed by burning feeling in the eyes and hard to keep them open is a sign of fatigue. This project has made provision to detect yawning based on the contour near the mouth area using circular Hough transform (CHT). This technique presents an intuitive way of extracting the mouth section and analyse it provided the environment is bright enough.

A holistic driver assistance system does not only detect the status of the driver without notifying them. Notifying does not mean intruding or altering driver's driving style. However, an audio speech alert would be activated when all the criteria of drowsiness are detected. Hence, consistent monitoring and detection of early signs of fatigue are crucial in ensuring road safety. Such sophisticated implementation usually requires substantial number of measuring instruments. So, a more sustainable approach with high accessibility and affordability should be studied and implemented to improve road driving quality.

1.1 Problem Statement

Currently, there are experimental methods that relies on brain activities to determine if the driver is drowsy. The methods involved the use of Electroencephalogram (EEG) & Electrooculography (EOG) that attach series of electrodes in the scalp to detect brain waves and eye movement, respectively. These electrodes detect small voltages from the brain which provide information on the drivers' status. Though such method can yield accurate results, however, it is deemed impractical as it requires extensive wiring which will annoy the driver and causes inconvenience (Triyanti, 2017).

Visual display is becoming a norm in most modern vehicles where assistive information is provided to aid the driver in decision making. However, such design imposes a distraction for the driver as too much information may limit the speed for driver to make decisions (Glinton, 2017). Besides, the glaring light from the visual display unit can also cause unwanted distraction and hazardous risk to the driver.

1.2 Aims and Objective

1. Implement image processing framework in detecting closed eyes and yawning of the driver using mobile devices.

2. To implement speech-based audio feedback feature when the algorithm detects the driver's closed eyes and/or yawning activity using mobile devices.

1.3 Scope

In this project there are several assumptions and constraints established to facilitate the development:

a) Image processing algorithms results are based on clear computer vision without any interference or noise from the environment. Hence, image with dark background is considered as noisy image and will be nullified since mobile devices have no infrared cameras.

b) Testing and review of the product are done on a typical 5-passenger vehicle. Lorries and heavy trucks are not included during testing phase of this project.

c) Feedback only refers to speech-based audio mechanism in which the product software does not interfere with the drivers' physiological actions. For instance, the product software would only recommend the driver to stop and rest but does not decelerate the vehicle involuntarily.

d) Hardware device includes only an Android mobile device. There are no additional hardware or chips involved.

1.4 Brief Methodology

a) Data Collection

A mobile device with at least 5 mega pixels frontal camera would be fixed onto a platform facing the driver seat on a typical 5-passenger vehicle which record real-time facial images of the driver.

b) Image Processing

i) Microsoft Cloud Services

Microsoft Azure Face application program interface (API) will be used to perform analysis on the data images that are obtained using the mobile device.

ii) *Open Source Computer Vision*

Google APIs would be utilised to extract and analyse the image datasets. Yawning and eye-closure algorithm would also be applied to obtain the results to provide relevant feedbacks.

c) Mobile Application Development

This project utilises the Android Studio Development Kit to integrate the image processing algorithm with Android environment. The integrated software would be set to run on mobile devices.

1.5 Significance of Project

This project will help to reduce the number of accidents involving drowsy drivers. Being able to detect yawning and eye closure, the feedback mechanism should be able to alert them non-intrusively using speech-based audio.

1.6 Project Schedule

Figure 1.1 shows the timeline of this project. The project starts from 7 September 2019 and is expected to end on 24 April 2020 which takes approximately 8 months to complete.

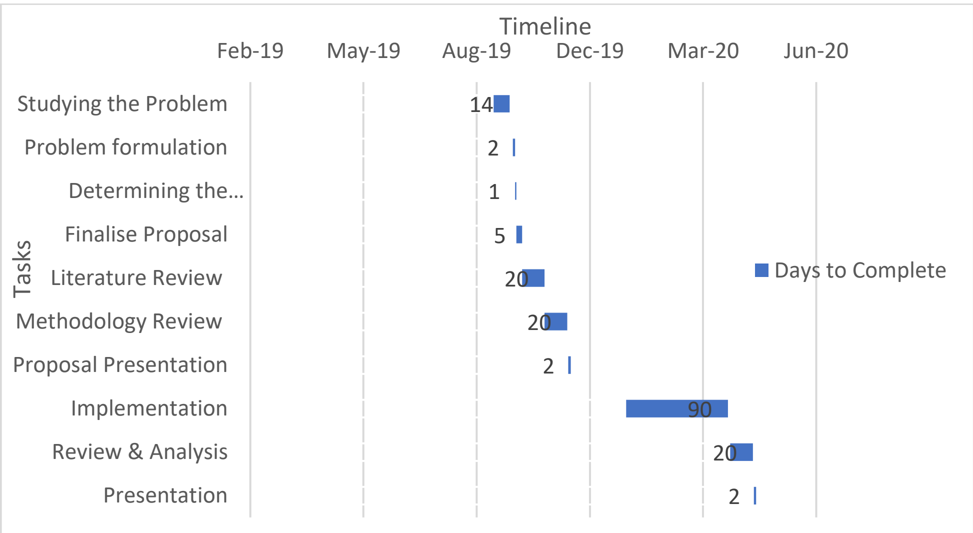

Figure 1.1: Estimated Project Timeline

1.7 Expected Outcome

An Android mobile application prototype framework that can detect eye closure and yawning with drivers' facial features and provide appropriate speech-based audio feedback to alert the user supported by experimentations and test results.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

As the rate of road accidents related to driver's performance has been steadily increasing over the years, there were many initiatives being conducted to solve such issue. This section of the paper discusses the ongoing or existing studies conducted related to driver's drowsiness monitoring system. Drowsiness on the road may be due to circadian-rhythm disorders and diseases which may affect even a well-rested driver. Researchers relies on physiological features in drivers that reflects the status of driver. These features include changes in facial landmarks like eye and mouth that indicates that the driver is drowsy and may affect their driving performance.

Over the decades, numerous experiments and studies have been introduced while some are tailored specifically to monitor driver's drowsiness. Usually when a person becomes drowsy, there is a reduction in inputs to the thalamic motor projections to the face, including the eyelids, causing these muscles to relax, resulting in increasingly longer periods of eyelid closure (Culebras, 2002). Using special scientific devices, the voltage difference between eyes can be computed to define if the driver is drowsy. Though such method proved to be minimal in error, however, it is not without limitation. The use of special devices requires huge number of sensors and wirings (Khan, 2019).

Another study suggests that frequent yawning followed by burning feeling in the eyes and hard to keep them open is a sign of fatigue (Riemersma et al., 1977). According to Illingworth (1988), the research has made provision to detect yawning based on the contour near the mouth area using circular Hough transform (CHT). This technique presents an intuitive and efficient approach in extracting the mouth section and analysing it to classify if drowsiness is imminent. Moreover, the use of machine learning as classification method has been increasingly popular in this field. Many researches have been conducted to illustrate the accuracy and reliability on using artificial intelligence to assist in monitoring driver's status using a variety of approaches.

With the advancement in computing technologies combined with artificial intelligence, performing facial analysis can be achieved with computer vision. Several key techniques and strategies would be further elaborated in this section to identify their advantages and disadvantages. By having clear comparisons on every method available allow research to make significant adjustment to the new product. Therefore, enhancing the development progress in the current field of interest.

2.1 Background of Computer Vision

Computer vision is a field of study focused on the problem of helping computer to see. "On abstract level, the goal of computer vision problems is to use the observed image data to infer something about the world" (Jason, 2019). Computer vision can be regarded as a multidisciplinary field that could widely be labelled as a subfield of artificial intelligence and machine learning. *Figure 2.1* shows the relationship between computer vision and artificial intelligence.

Computer vision is widely found in many scientific fields including engineering, automotive and computer security. Computer vision may seem easy, because it is so effortless for humans. However, there are numerous challenges have yet to be solved. Perhaps it is because computer researchers are having not fully understand the complex biological vision in human. Hence, creating a barrier in modelling the concept into machine codes.

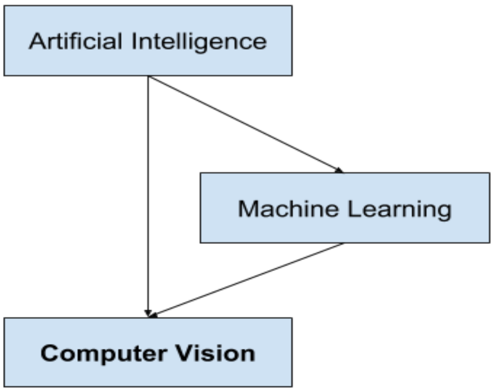

Figure 2.1: Relationship of AI and Computer Vision

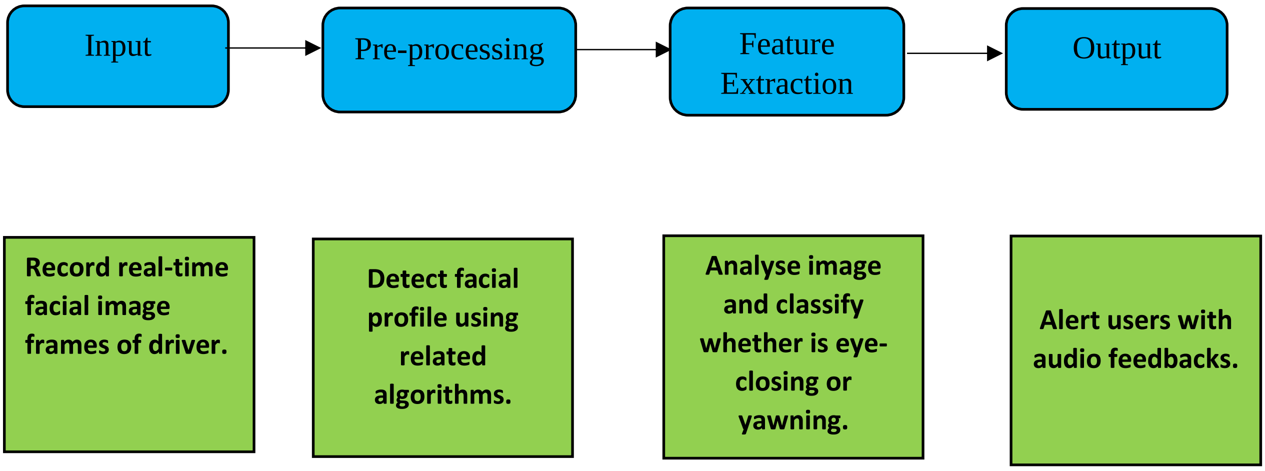

Figure 2.2: General pipeline for computer vision

In the automotive industry, computer vision has been an emerging concept to monitor driver's performance as monitoring driver's long-distance performance can be cumbersome. *Figure 2.2* shows the flow of data images in a typical computer vision approach. With the help of modern technologies, there have been numerous driver monitoring experiments being conducted to improve road performance and safety. The existing research can be categorised into two different approaches namely monitoring with the use of dedicated devices and monitoring using computational algorithms. These approaches measure the performance of the driver throughout the entire journey under controlled circumstances.

2.1.1 Measuring driver’s performance using special devices

i) Measuring eye movement using Electrooculography (EOG)

Using this technology as a measuring tool to gauge driver’s eye movement to determine drowsiness level yield accurate results. The driver is expected to connect an extensive number of electrodes that would be placed on their forehead just few centimetres above their eyes. The electrode then measures the potential difference based on the eye cornea movement. For example, a blink is detected when the contact between eye’s upper and lower lids lasts for about 200-400ms, and microsleep is detected if the eye remains closed for more than 500ms (Khan, 2019). The results of the waves are recorded digitally.

Based on the procedures mentioned, driver’s driving performance are monitored based primarily on eyeball movement, blink duration, blink frequency and eye closure duration. By knowing the eye closure duration, it is possible to calculate the percentage of difference of eye closure or simply known as PERCLOS.

ii) Measuring brain waves for drowsiness with Electroencephalogram (ECG)

The ECG produces a graph of electrical activity of the heart on a voltage versus time scale. The result obtained is used to determine the driver’s heart rate and heart rate variability (Khan, 2019).

Heart Rate (HR)

A decrease in heart rate is reported during long drives at night (Riemersma, 1977). Moreover, a driver’s emotions, mental activity, and body exertion also affect the heart rate (Wilson, 1988).

Heart Rate Variability (HRV)

HRV is the change in the time interval between two successive heart beats. The activities of autonomous nervous system (ANS) change due to fatigue or stress can be efficiently detected using HRV (Mulder, et al., 1973). Typically, during the type of activities, HR increases HRV decreases (Mulder, et al., 1973). Apart from the HRV pattern, the power spectral analysis of HRV also provide valuable information for drowsiness detection (Furman, 2008).

2.1.2 Measuring using computer vision approach

i) Face detection with Haar-like Classifier cascades

This is a popular method used in detecting edges and line within a digital image where it utilises the difference in colour pixels between two different area (Wang, 2018). However, such method has its limitation as its features are manually computed. When changes are made to an image, this method may find it difficult to detect the image feature.

ii) Eye closure detection using template matching algorithm

Traditionally, image input is being sent to match with a set of template images pre-determined by the developer. Each input is returned with confidence interval. The one with biggest match would be taken as the result. Despite its simplicity, the algorithm takes huge computational cost when the image template dataset expands (Wang, 2018). Template matching can be defined as the process of searching the target image (i.e., current frame of the video sequence) to determine the image region that resembles the template, based on a similarity or distance measure (Theodoridis, 2009).

As such, this method might not work well in environment that depends on real-time results as searching for a matching image can be computationally expensive.

iii) Yawning detection with Circular Hough Transform

Circular Hough Transform (CHT) is a basic technique in digital image processing for detecting circular objects in a digital image. It is a feature extraction technique used for detecting circles. However, the traditional approach of this method requires a lot of storage space and computation. Hence, a more adaptive approach was developed by Illingworth and Kittler (1987) using small accumulator array and the idea of flexible iterative "course to fine" accumulation and search strategy to identify significant peaks in the Hough parameter spaces which reduces the grid size to compensate for the computation speed.

2.2 Review on computer vision approach

2.2.1 Haar-like Cascade Classifier

Haar-like cascade is a popular approach in detecting objects within an image. Due to its simplicity, it offers robust implementation where only difference of pixel is used to determine an object. Apart from that, relatively high responsiveness, and accuracy when images are in good condition. Popular method used in many image processing functionalities. *Table 2.2* in *section 2.2.3* shows the summary of using this approach.