Driver Drowsiness Detection Using Visual Information on Android Device

Aldila Riztiane[1], David Habsara Hareva[2], Dina Stefani[3], Samuel Lukas[4]
[1,2,4]Computer Science Department and [3]Mathematics Department
Pelita Harapan University
Tangerang, Indonesia
aldila.riztiane@gmail.com, David.habsara@uph.edu, Dina.stefani@uph.edu, Samuel.lukas@uph.edu

***Abstract*—The number of casualties from road accidents keep arising each year. While there are many causes to road accidents, most are surprisingly caused by human errors, such as drowsiness. Therefore, this issue raises an idea for an application which will be able to track a person's eye movement while driving. The application, called "Driver Drowsiness Detection", runs on an Android handheld and wearable. The purpose of this application is to alert drivers so that they can be cautioned to pull over and stop driving in a drowsy state. The application "Driver Drowsiness Detection" utilizes Haar-cascade Detection as well as template matching in OpenCV to detect and track the eyes using the front camera of an Android device. Testing has been conducted to ensure that the functionality, behavior, performance and user satisfaction are as expected. Even though, the input received by the application still has several restrictions, specifically in correlation to sufficient lighting and obscurity of the face and eyes area, the application has successfully detected the eye blinks at the angle of 30 to 60 degrees and distance of 20-50 cm, as well as measuring the heart rate.**

Keywords—drowsiness detection; heart rate; template matching

I. Introduction

The increasing number of traffic accidents are attributed to human errors, especially drowsiness. The state of drowsiness causes people to lose their vigilance, hence becoming a danger not only to themselves, but also their surroundings. Fletcher et al. in [1] has mentioned that 30% of all traffic accidents have been caused by drowsiness. It was demonstrated that driving performance deteriorates with increased drowsiness with resulting crashes constituting more than 20% of all vehicle accidents [2].

Drowsiness is often caused by four main factors: sleep, work, time of day, and physical [3]. Drowsiness can be detected throught three main categories. They are vihicle based, behavioural based and physiological based, [4]. Vehicle based measures a number of metrics, including deviations from lane position, movement of the steering wheel, pressure on the acceleration pedal, etc. Behavioural based measures the behaviour of the driver, including yawning, eye closure, eye blinking, head pose, etc. Physiological based measures the correlation between physiological signals ECG (Electrocardiogram) and EOG (Electrooculogram). It is detected through pulse rate, heart beat and brain information.

A number of factors have been reported to characterize sleepy-related accidents. The first would be the time of the day. Data shows that most crashes caused by drowsiness occur from midnight to 8 a.m. and from 1 p.m. to 3 p.m. Second, most crashes involved someone driving alone. A single drive usually has no one to talk to and no one to help keep them alert. Lastly, there are no signs found of the driver attempting to avoid the crash. This third characteristic can be seen from the lack of skid marks at the scene, indicating that the driver did not hit the brake. It is also observed that the car did not try to swerve out of the way. These characteristics show that drowsy-related accidents can be avoided by embedding an application that can be used to measure drowsiness to a mobile device to assist a driver while driving. This paper discusses how to build the application by measuring behavioral and physiological of the driver while driving especially when he or she is alone.

II. Related Theory

A. Various Drowsiness Detection Techniques

Fuletra and Dulari [5] stated that there are three various techniques being used by researchers to detect drowsiness. They are images processing based techniques, artificial neural network based techniques and electroencephalograph (EEG) based techniques. In image processing based techniques, drivers face images are used for processing so that one can find its states. From the face image one can see that driver is awake or sleeping. Using same images, they can define drowsiness of driver because in face image if driver is sleeping or dozing then his/her eyes are closed in image and other symptoms of drowsiness can also be detected from the face image. These techniques are classified in three sub-categories; template matching technique; eye blinking based technique and yawning based technique.

In template matching technique, the states of eye of the driver can be deteted. If driver closes eye/s for a certain periode then it indicates the drowsiness. This method is simple and easy to implement. Researchers have used this technique [6].

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In eye blinking based technique, eye blinking rate and eye closure duration is measured to detect driver's drowsiness. Because when driver felt drowsy at that time his/her eye blinking and gaze between eyelids are different from normal situations so they easily detect drowsiness. In this system the position of irises and eye states are monitored through time to estimate eye blinking frequency and eye clouse duration, [7]. This type of system uses a remotly placed camera to aquire video and computer vision methodes are then applied to sequentially localize face, eyes and eyelids positions to measure ratio of closure [8].

In yawning based technique, number of yawn is counting in a certain time since this is as one of the symptoms of fatigue. The yawn is assumed to be modeled with a large vertical mouth opening. Mouth is wide open is larger in yawning compared to speaking. Using face tracking and then mouth tracking one can detect yawn [9]. They detect yawning based on opening rate of mouth and the amount changes in mouth contour area as shown in Fig. 1 [5].

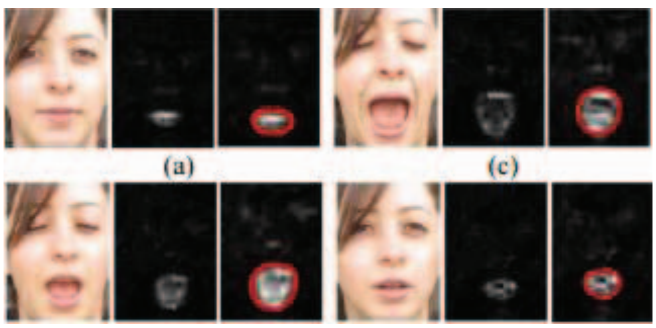


Figure 1. (a) Normal mouth image (b) Staring yawn image (c) Wide open mouth larger then speaking its yawn (d) Closing mouth completing yawn.

Applying EEG based technique is compulsory to wear electrode helmet by drivers while driving. This helmet has various electrode sensors which placed at correct place and get data from brain. Ming, Zhang and Fu have used the characteristic of EEG signal in sleepy driving. Their experimental results show that the method presented in this paper can be used to determine the drowsiness degree of EEG signal effectually.

Figure 2. EEG data acquisition system

In artificial neural network based technique, some researchers [11] are carrying out investigations in the field of optimization of driver drowsiness detection using Artificial Neural Network. Visual behaviors that typically reflect a person's level of fatigue such as the eyes, gaze, head movement, and face include eyelid movement and facial expression.

B. Drowsiness Measurement based on Blink Behavior

Eye blinks were defined as the period of eyelid closures that lasts from 50 to 500 ms. An eyelid closure that lasts about more than 500 ms and covers the pupil for that amount of time is usually defined as micro sleep. The four stages of Drowsiness stages are: awake, reduced vigilance, fatigued, and sleepy. The transition from awake stage to reduced vigilance was indicated by an increase in blink frequency alone, whereas the transition to severe drowsiness was accompanied by an increase in blink duration as well, as summarized in Table I.

TABLE I. DROWSINESS STAGES BASED ON BLINK BEHAVIOR

Drowsiness Stage	Description
Awake	Long blink intervals and short blink durations
Reduced (low) vigilance	Short blink intervals and short blink durations
Drowsy	Long blink durations
Sleepy	Very long blink durations and/or single sleep events and/or a low eyelid opening level

Blink intervals refer to the period between one blink to another, while blink durations refer to the period in which the eyelids are closed. During the drowsy stage, a person will have long blink durations, which means that the eyelid closure will last for a lengthy amount of time. An infrared (IR) reflectance method was used to measure the duration each components of blinks, which includes; eyelids closing, remaining closed, and reopening, on subjects who were alert and when they were drowsy. Fig. 3 shows the result of the experiment.

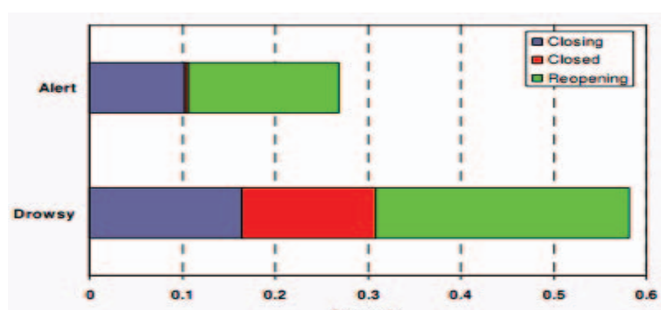


Figure 3. Blink duration differences between alert and sleepy subjects

Fig. 3 shows that when the subject is alert, the period of eyelids closing is shorter than when the subject is in a drowsy state. Furthermore, there is a more significant difference in the amount of time where the eyelids are closed between the alert and drowsy condition. It also took a much longer time for drowsy subjects to reopen their eyelids than those who are alert, therefore it is said that when a person is drowsy they tend to have longer blink durations [12].

III. System Design

The system design for drowsiness detection application can be summarized as follow. First, the driver will be asked to measure their heart rate using the wearable device to obtain the normal resting heart rate, as it differs for every individual. Once the measurement has been saved, it will be a parameter to determine the value indicated as Normal, Drowsy, or Sleeping. These values will be acquired after the heart rate measurement testing to determine the drop value from normal heart rate to sleepy.

Once the measurement is taken and saved, the driver will be able to start the application which will detect the face, and primarily the eyes area of the driver. The application will detect the state of the eyes, whether it is shut or open. The two parameters, which are the heart rate and the state of the eyes will then be combined to determine whether the driver is categorized to being sleepy or not.

A. Device Spesifications

In order to run the application of Driver Drowsiness Detection, there are two devices needed. The first is an Android-based smartphone with front camera, and second an Android Wear-based wearable device. There are also recommended hardware and software specifications to ensure that the application runs as desired. The recommended device specifications needed to run the application are as follows:

1. Handheld device with front-facing camera
2. Wearable device with heart rate monitoring capability

The recommended software specifications needed to run the application are as follows:

1. Android operating system 4.2 (Jelly Bean) or higher
2. Android wear OS for wearable
3. OpenCV manager for device

B. Device Placement

The devices used to run Driver Drowsiness Application needs to be situated not only to ensure the highest efficiency, but also not disrupting the user, which needs to use the application while driving. The first device, which has the front camera, is placed in front so that it can have a clear view of the user's facial features. The distance and angle of the placement will be determined after testing is conducted. The device can be placed somewhere on the dashboard of the car using a phone holder specifically designed to be used in the car.

The second device, which is the wearable, needs to be worn by the user to continuously measure the heart rate. While wearing it, the user needs to restrict his or her activities to a minimum, because excessive movements can hinder the wearable from taking measurements, as illustrated in Fig. 4.

C. Application Framework

The input driver's face image will be acquired real-time using the front-camera of the device by using the library function face detection, in OpenCV. Once the face has been detected, a draw rectangle function will be called upon to mark the face area. Afterwards, the region of interest (ROI) will be reduced to the eye area, and again the function will be called to mark the eye area. When both the face and the eyes detection, the next step would be to determine when the eyes are open and when they are closed. The blink detection process will be done using the template matching method.

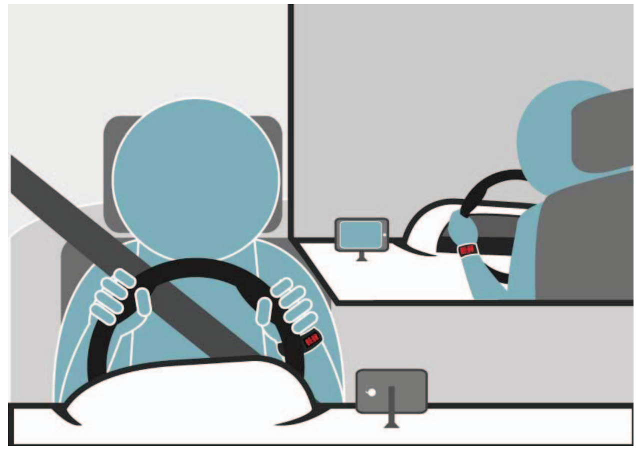


Figure 4. Device placement scenario

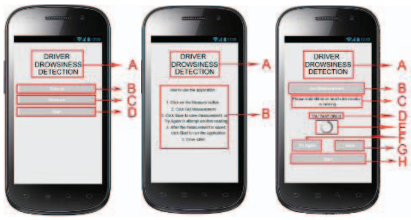
The template matching method returns a value called minVal to find the darkest area of an image, which in case of a face, is the pupil of the eyes. Hence, the process of detecting blink could rely upon the existence of such value. The value will not be returned when the eyes are closed, since it is not detected. When the eyes are open, it will range from 0 to 5. The minVal will then be one of the deciding conditions to trigger the alarm. However, the blink duration also needs to be taken into account to determine Drowsiness.

The blink duration of a drowsy person is said to be approximately 0.6 seconds, hence the value that will be used for the application will be 0.6 seconds. A countdown timer function will be activated to count whether the minVal has fallen out of range for a period of 0.6 seconds. When such condition has been met, the application will check for one more condition, which is the heart rate, to determine Drowsiness and triggering the application.

Since there is no exact heart rate value that can be applied as a standard to every individual, testing for the sole purpose of this application will be conducted to determine the drop of an individual's heart rate between three stages; alert, drowsy, and sleeping. The heart rate value, measured in beats per minute (bpm) will be another deciding factor to trigger the alarm.

IV. Implementation and Testing

The main menu of the Driver Drowsiness Detection consists of four parts. They are the name of the application, the Tutorial button that will take the user to the tutorial page, the Measure button that will take the user to measure their heart rate and the Start button that will run the application as illustrated in Fig. 5.



(a) (b) (c)

Figure 5. (a) Main menu (b) Tutorial page (c) Measurement page

In tutorial page there are a set of instruction on how to operate the system. Firstly, click on the measurement button. Secondly, click get measurement to measure the normal heart rate of the driver. Thirdly, click to save measurement or try again to attempt another reading. Fourthly, after saving the measurement, click start to run the application. The result after pressing the start button is shown in Fig. 6.

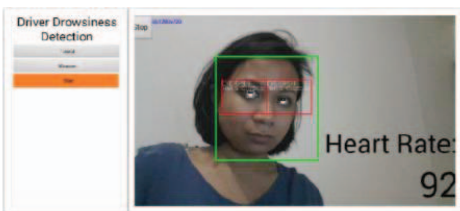


Figure 6. Displaying when Start button is pressed

A. *Eye Detection Functionality Testing*

The testing for eye detection is done to determine the placement of the device to achieve the highest accuracy. Testing is conducted by placing the device on various distances and angles on three degrees. The result of the testing is summarized on Table II.

TABLE II. CAMERA PLACEMENT TESTING

Angle	Distance (cm)									
	20	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**
30	ok	ok	ok	ok	ok	ok	ok	ok	fail	ok
45	ok	ok	ok	ok	ok	ok	ok	fail	ok	fail
60	ok	ok	ok	ok	ok	ok	ok	ok	fail	fail

The result of the testing shows that when the camera is placed on the angle from 30 to 60 in front to the driver's face, and within the distance of 20 to 50 cm, the application will successfully detect the driver's face. However, the application will fail to detect the face when it is placed on the angle of 45°, within 55 and 65 cm from the driver, and on the angle of 600, within 60 and 65 cm. Therefore, it can be concluded that the ideal placement of the camera would be on the angle ranging from 30 to 60, and the distance ranging from 20 to 50 cm.

B. *Heart Rate Monitor Functionality Testing*

Heart rate monitor functionality testing is conducted with the purpose to acquire the variation of heart rate on subjects in three conditions; normal, drowsy, and asleep. The values are also collected to determine the percentage in which the heart rate drops from each state so it can be a parameter that can be used in the application. The testing is done on 5 subjects using wearable device to acquire heart rate, which is measured in beats per minute (bpm). The results of the testing are shown in Table III. It means subject 1 has the average normal heart rate of 95.2, average drowsy heart rate of 78.7, and average sleeping heart rate of 63.9. Therefore, the heart rate drops 17% from normal to drowsy, and 19% from drowsy to sleeping. The average of the heart rate drops from the 5 subjects is 20% from normal to drowsy, and 12% from drowsy to sleeping. This is as the reference to detect the driver's Drowsiness in this system.

TABLE III. HEART RATE MEASUREMENT FOR SUBJECT 1

No.	Subject 1		
	Normal	**Drowsy**	**Sleeping**
1	94	73	62
2	91	77	63
3	106	71	64
4	93	74	66
5	97	85	67
6	92	73	64
7	95	82	62
8	97	80	64
9	94	87	63
10	93	85	64
Average	**95.2**	**78.7**	**63.9**

V. CONCLUSION

After the application Driver Drowsiness Detection is developed using Java and OpenCV programming language in Android Studio, and based on the theories, testing, and implementation, it can be concluded that:

1. The ideal camera placement is on the angle of 30° to 60° and the distance ranging from 20 to 50 cm perpendicular to the face.
2. The testing result determined for the purpose of this application is that drop percentage between alert and drowsy state is 20%.

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