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Cite as: AIP Conference Proceedings **2097**, 030104 (2019); https://doi.org/10.1063/1.5098279
Published Online: 23 April 2019

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Drowsiness Detection System Design based on Individual Driver

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Abstract. There are four main factors causing the accident on the highway: the first is the sleepy driver, the second is the condition of the vehicle used, the third is the road factor, the fourth is the environmental factor. The human eye in a normal physical state has a different size, so that when a person who has large eyes when drowsy then the large opening of his eyes will be different from the size of the eyes of someone who has small eye size. Therefor in this research the system was designed by taking a unique eye reference per person. Preliminary data retrieval is taken when the driver starts driving a vehicle assuming the initial condition of the driver is not drowsy. This initial data will be used as a reference for threshold decision making in the process of determining drowsiness in subsequent experiments. In this research using the EAR value of each driver from the initialization process, and the EAR value is also used as a baseline for stating a driver's eyes are closed or open based on the EAR threshold. If the EAR value (from driving process) is below the threshold for several consecutive times (with a reference of 1.5 seconds) the driver will be detected drowsy by the system. If detected drowsiness, it will be given a response in the form of motor vibration and sound. The drowsiness detection system has been designed using the proposed EAR threshold method from each ratio of eyes each individual driver. From this research get the EAR driver is 0.03-0.69. EAR_{min} for each driver is in the range: 0.03-0.18 and EAR_{max} for each driver in the range: 0.35-0.69. The minimum value of the EAR threshold is 0.20 and the maximum value of the EAR threshold is 0.41. From the four times the drowsiness detection system testing, the system successfully to detect drowsiness from each driver.

INTRODUCTION

According to the data obtain by Korlantas POLRI (Traffic Police Corps of Indonesian Republic) at September 2018, the number of traffic accident in Indonesia has increased per three month (Figure 1).

The 4th International Conference on Industrial, Mechanical, Electrical, and Chemical Engineering
AIP Conf. Proc. 2097, 030104-1–030104-8; https://doi.org/10.1063/1.5098279
Published by AIP Publishing. 978-0-7354-1827-1/$30.00

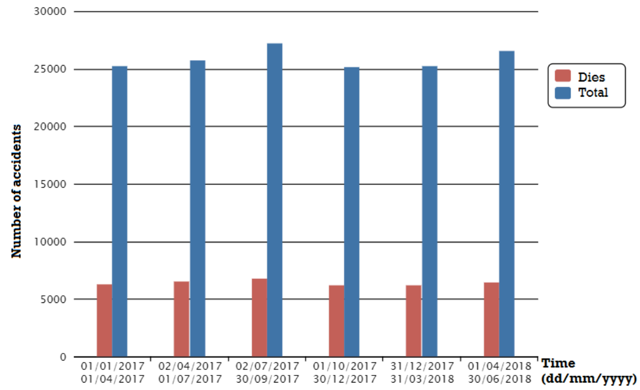


FIGURE 1. Accident Fatality Chart[1]

From figure 2 the number of accident victims is based on the age group, there are 3 the highest group of age who have many accidents, including productive age, namely: 15-19, 20-24 and 25-29 years[1]. The number of accidents occur in drivers aged 15-19 years totaling 5600 accidents, 20-24 years a number of 4500 accidents, and 25-29 years of 3000 accidents. Therefor the experiment in this research was carried out by the productive age of 15-29 years old.

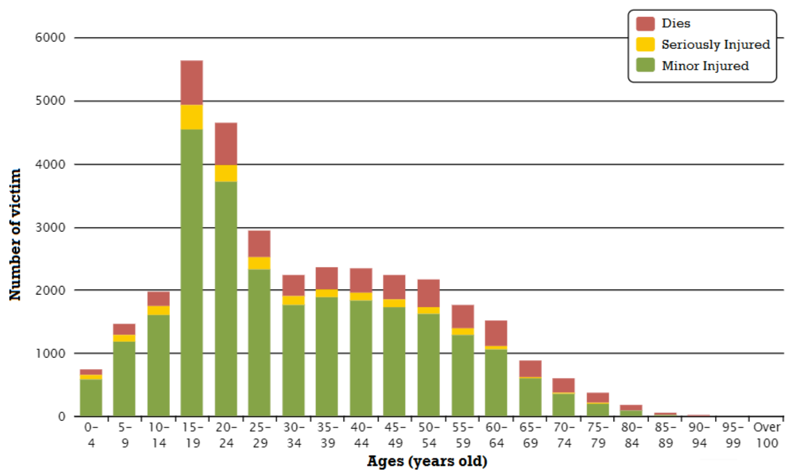


FIGURE 2. Accident Fatality Chart[1]

There are many factors that cause traffic accidents: There are four main factors causing the accident on the highway: the first is the sleepy driver, the second is the condition of the vehicle used, the third is the road factor, the fourth is the environmental factor[2].

Research on Drowsiness detection has been carried out by Amna Rahman, Mehreen Sirshar and Aliya Kahn, discussing drowsiness detection in real time using eye blink monitoring[3]. The Algorithm of Eye Blink Detection uses Harris Corner Detector to find the two eye corner points and one point at the lower eye lid. Then calculate the midpoint between two eye corner points. Find the distance from the midpoint and one point at the lower eye lid. Eye state classified into open condition and close condition. The close condition if the distance is zero or close to zero, the open condition otherwise. Drowsiness detection uses eye closure with two second time frame durations, because the drowsiness condition must be beyond averages of blink human duration 0.1-0.4 second[3].

Research on real-time eye blink detection using facial landmarks has been carried out by Tereza Soukupova and Jan Cech. From facial landmark that are detected, then derive the Eye Aspect Ratio (EAR) that is used as an estimate of the eye open state. EAR threshold used in this research is 0.2[4].

The human eye in a normal physical state has a different size, so that when a person who has large eyes when drowsy then the large opening of his eyes will be different from the size of the eyes of someone who has small eye size. Even in certain cases a person with large eyes when drowsy will have the same large openings as the eyes of a small person, whereas people with small eyes are not drowsy.

Therefore in this research the system was designed by taking eye reference based on individual driver. Preliminary data retrieval is taken when the driver starts driving a vehicle assuming the initial condition of the driver is not drowsy. This initial data will be used as a reference for EAR threshold decision making in the process of determining drowsiness/ sleepiness in subsequent experiments.

DRIVER DROWSINESS DETECTION & MEASUREMENT METHODS

For drowsiness detection & measurement methods there are five categories, such as: subjective, physiological, vehicle-based, behavioral and hybrid[5].

a. Subjective Methods

Subjective methods to measure the drowsiness level based on questionnaires and electro-physiological measures of sleepiness. There are subjective tests of sleepiness, such as Epworth Sleepiness Scale (ESS), Multiple Sleep Latency Test (MSLT), Maintenance of Wakefulness Test (MWT), Stanford Sleepiness Scale (SSS), The Karolinska Sleepiness Scale (KSS), Visual Analogue Scale (VAS)[5].

b. Physiological Methods

Physiological methods to measure the drowsiness level based on experiment with electro-physiological signals of the human body, such as electrocardiogram (ECG), electroencephalogram (EEG), and electrooculogram (EOG)[5].

c. Vehicle-Based Methods

Vehicle-Based methods to measure the drowsiness level based on subjective evidence, typical drivers' and vehicles' behavior. The common Vehicle-based methods used are the steering wheel movement (SWM) and the standard deviation of lane position (SDLP).

d. Behavioral Methods

Behavioral methods to measure the drowsiness level based on detecting specific behavioral driver while in a drowsy state. Body expressions such as: rapid, constant blinking, nodding or swinging of the head, or frequent yawning. Usually the systems use camera to detect this method.

One of the parameters used for detecting eye blinks is Percentage of eyelid Closure over the pupil over time (PERCLOS) which used to determine drowsiness based on blinking frequency[6,7]. Besides PERCLOS, there are Eye Aspect Ratio (EAR) based on eye opening ratio[4]. EAR is a calculation of the aspect ratio of the eye which is the relationship between height and width of the eye based on landmarks in the eye. This method was proposed by Tereza Soukupova and Jan Cech. EAR values can be found with the following conditions (see figure 3).

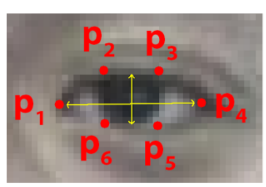


FIGURE 3. Eye Point of EAR

$$EAR = \frac{\|P2 - P6\| + \|P3 - P5\|}{2\|P1 - P4\|} \quad (1)$$

In this research using Behavioral method for drowsiness detection & measurement, based on Eye Aspect Ratio specify for unique person.

e. Hybrid Methods

Hybrid methods are based on combination of two or more drowsiness method, such as combined between behavioral methods and vehicle-based methods or others. The hybrid methods showed that the reliability and accuracy of the created hybrid method was significantly higher than those using a single methodology approach[8].

DROWSINESS DETECTION SYSTEM DESIGN

The following are hardware design and block diagram for Drowsiness Detection System.

A. Hardware Design

Hardware design of drowsiness detection systems can be seen in figure 4.

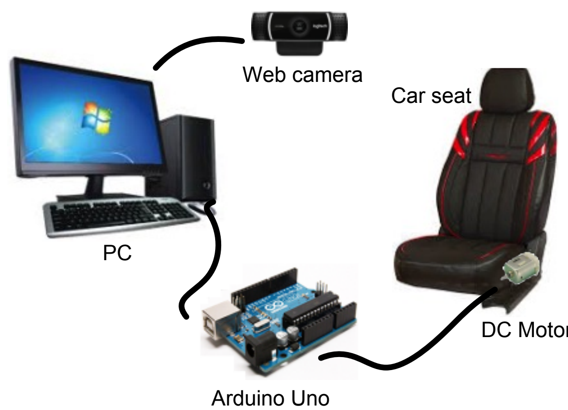


FIGURE 4. Hardware Design of Drowsiness Detection System

Hardware design specification for this system using: web camera (Logitech C922), CPU (Prosesor Intel Core i5-7200U 2.5GHz), Arduino Uno, and DC motor. While driving process, the driver's face and driver's eyes are captured using the camera. If the Eye Aspect Ratio (EAR) under the EAR threshold, the system will detect the driver in a drowsy. If drowsiness is detected, the DC motor placed in the seat car will vibrate and the system will emit a sound.

B. Block Diagram System

Figure 5 shows the block diagram of the drowsiness detection system, which consists of two main process. The first main process is an initialization process to get the EAR baseline from each driver. The EAR baseline becomes the EAR threshold to determine the limit of the eye ratio of each driver. Furthermore, the driving process is carried out, is the process of testing drowsiness detection, in this process the EAR calculation of the driving process will be calculated then compared with the EAR threshold, the result of the system decision states a driver is drowsiness or awake.

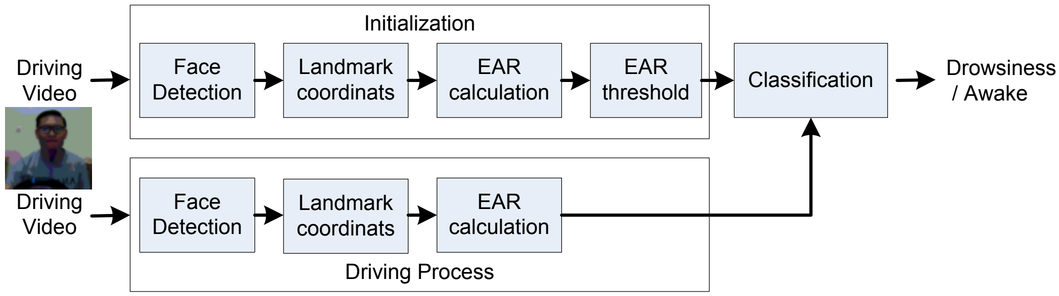


FIGURE 5. Block Diagram System of Drowsiness Detection

The explanation of each process is as follows:

- Face Detection

The driving video is taken using a web camera, then preprocessing process is resized the image, and then change the color of image into grayscale. Next process is the face detection process using Histogram of Oriented Gradient (HOG). HOG can detect objects by detecting the distribution of local gradient intensity values or edge direction in images[9]. Face objects detected are then marked with a bounding box.

- Landmark coordinates

The next process is looking for landmark coordinates. Landmarks are points that are related to each object that fits between or in its population. In this research is using 68 landmarks points to identify faces and parts, with landmark models that had been trained first. Results from landmark points can be seen on figure 6.

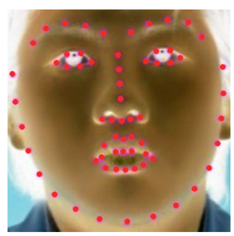


FIGURE 6. Face Landmark Points

- EAR Calculation

Coordinates of the landmarks point on the face, especially the eye are taken and then calculate the EAR value. The EAR value of the left and right eye is taken then averaged.

- EAR threshold

The proposed method to get the EAR threshold of each driver is to use the maximum EAR and the minimum EAR values obtained from the initialization process. This process is considered as the initial condition of the driver that will be used as a baseline. The EAR threshold is determined by taking the middle value between the maximum EAR and the minimum EAR. The EAR threshold values used in this research are as follows:

$$EAR_{threshold} = \frac{EAR_{max} + EAR_{min}}{2} \tag{2}$$

- Classification

To classify a driver in drowsiness or awake, in this research using the EAR value of each driver from the initialization process, and the EAR value is also used as a baseline for stating a driver's eyes are closed or open based on the EAR threshold. If the EAR value (from driving process) is below the EAR threshold for several consecutive times (duration of closing eye is 1.5 seconds) the driver will be detected drowsy by the system.

Based on the Law of the Indonesia Republic about the Traffic and Transportation Highway state that the minimum speed vehicle at 60 km/hour or 16.67 m/s[9]. And according to the Indonesian National Police, the secured distance between vehicle is 60 meters[10]. So the secured time between vehicles is 3.6 seconds. According to McWilliams that the average human blink is 0.1-0.4 seconds. In this research was decided that the maximum duration of closed eyes was 1.5 seconds for accident anticipation.

If the system detected drowsiness, it will be given a response in the form of motor vibration and sound. See fig. 7 The drowsiness detection system flowchart.

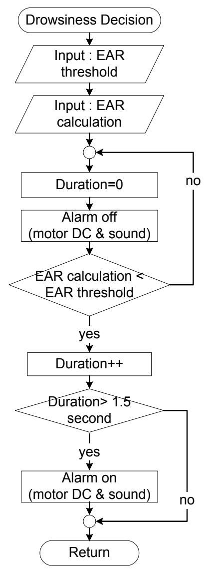


FIGURE 7. Flowchart of The Drowsiness Detection System

RESULTS

From the results of the initialization process, EAR is obtained for each driver as follows:

TABLE 1. Table of EAR Driver

Driver	EAR_{min}	EAR_{max}	$EAR_{Threshold}$
D1	0.08	0.44	0.26
D2	0.18	0.53	0.35
D3	0.14	0.39	0.26
D4	0.15	0.47	0.31
D5	0.06	0.40	0.23
D6	0.10	0.41	0.25
D7	0.11	0.39	0.25
D8	0.03	0.38	0.20
D9	0.11	0.50	0.30
D10	0.06	0.37	0.21
D11	0.10	0.43	0.26
D12	0.09	0.40	0.24
D13	0.11	0.43	0.27
D14	0.11	0.35	0.23

TABLE 1. Continued

Driver	EAR_{min}	EAR_{max}	$EAR_{Threshold}$
D15	0.13	0.69	0.41
D16	0.12	0.41	0.26
D17	0.16	0.37	0.27

From Table 1, EAR_{min} for each driver in the range: 0.03-0.18 and EAR_{max} for each driver in the range: 0.35-0.69. The minimum value of EAR threshold is 0.20 and the maximum value of EAR threshold is 0.41. The chart of EAR threshold is charted the results can be seen fig. 8.

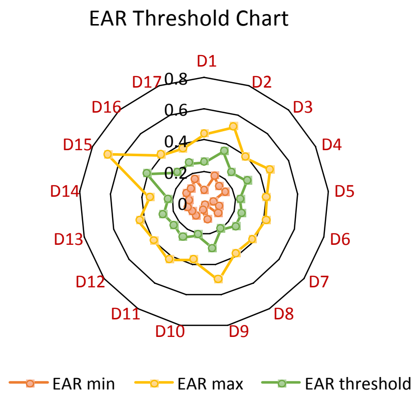
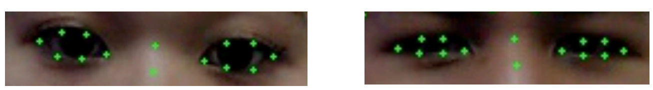


FIGURE 8. EAR Threshold chart

From fig. 8 can conclude that EAR for individual driver is 0.03-0.69. It will affect for the driver has big eyes (fig. 9a) seems never to close his eyes and the driver has small eyes (fig. 9b) seems often closes his eyes. So, from this table & graph it can be concluded that individual driver has a unique EAR depending on the eye ratio.



a. Big Eyes b. Small Eyes

FIGURE 9. Example of eyes driver

To test drowsiness detection, in this research four times the driving process was taken for each driver. Each driving process is carried out for 10 minutes. In Table 2, the least number of drowsiness is zero times and the most is 135 times. The driver who was not detected drowsiness at all from four times testing was the driver D13.

TABLE 2. Table of Number of Drowsiness each Driver

Driver	Number of Drowsiness each Driver			
	Test 1	Test 2	Test 3	Test 4
D1	13	7	11	0
D2	83	97	135	99
D3	7	2	0	0
D4	3	2	6	0
D5	0	2	3	0
D6	0	2	2	2
D7	0	0	2	7
D8	1	0	0	0
D9	17	20	17	0
D10	0	2	2	0
D11	24	62	87	13
D12	2	32	61	17

TABLE 2. Continued

Driver	Number of Drowsiness each Driver			
	Test 1	Test 2	Test 3	Test 4
D13	0	0	0	0
D14	0	0	0	5
D15	0	0	4	0
D16	13	31	59	38
D17	1	3	27	0

CONCLUSION

The drowsiness detection system has been designed using the proposed EAR threshold method from each ratio of eyes each individual driver. From this research get the EAR driver is 0.03-0.69. EAR_{min} for each driver is in the range: 0.03-0.18 and EAR_{max} for each driver in the range: 0.35-0.69. The minimum value of the EAR threshold is 0.20 and the maximum value of the EAR threshold is 0.41. From the four times the drowsiness detection system testing, the system successfully to detect drowsiness from each driver.

In future, research can be developed with EAR search that is right for each individual driver using a learning system. The sleepiness detection systems can be combined with two methods to improve accuracy of system.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Ministry of Research, Technology, and Higher Education of Indonesia for the funding through Penelitian Dasar Unggulan Perguruan Tinggi, under contract number 0815/K4/KM/ 2018.

REFERENCES

1. Indonesia, Korlantas, "Accident Count", http://korlantas-irsms.info/graph/accidentData, 2018.
2. Gridoto.com, "4 Faktor Utama Penyebab Kecelakaan di Jalan Raya", https://www.gridoto.com, 2018.
3. Amna Rahman, Mehreen Sirshar, Aliya Khan, "Real Time Drowsiness Detection using Eye Blink Monitoring", National Software Engineering Conference (NSEC 2015), 2015.
4. Soukupová, T., & Cech, J., "Real-Time Eye Blink Detection using Facial Landmarks", 21st Computer Vision Winter Workshop, February 3, 1–8, 2016.
5. Colic, A., Marques, O., & Furht, B, "Driver Drowsiness Detection Systems and Solutions (First)", Springer, London, 2014.
6. T. Abe, T. Nonomura, Y. Komada, S. Asaoka, T. Sasai, A. Ueno, and Y. Inoue, "Detecting deteriorated vigilance using percentage of eyelid closure time during behavioral maintenance of wakefulness tests", International Journal of Psychophysiology, 82(3):269–274, 2011.
7. Jun-Juh Yan, Hang-Hong Kuo, Ying-Fan Lin, Teh-Lu Liao, "Real-time Driver Drowsiness Detection System Based on PERCLOS and Grayscale Image Processing", International Symposium on Computer, Consumer and Control, 2016.
8. B. Cheng, W. Zhang, Y. Lin, R. Feng, and X. Zhang, "Driver drowsiness detection based on multisource information", Human Factors and Ergonomics in Manufacturing and Service Industries, 2012.
9. Republik Indonesia, "Undang-Undang No. 22 Tahun 2009 tentang Lalu Lintas dan Angkutan Jalan Raya", Sekretariat Negara, Jakarta, 2009.
10. Indonesia, Kompas "Panduan Jarak Aman Kendaraan Menurut Polisi", https://otomotif.kompas.com/read/2016/08/03/172300915/Panduan.Jarak.Aman.Kendaraan.Menurut.Polisi, 2016.
11. McWilliams, "Re: How fast does an eye blink?". University of Missouri- St. Louis. MadSci Network.