THE SYSTEM DESIGN FOR FATIGUE DRIVING DETECTIONBY BRAINWAVES ANALYSIS IN SMARTPHONE

Yung Gi Wu[1], Jwu Jenq Chen[2] and Rui Hsin Wang[3]

[1,2,3] Department of Computer Science & Information Engineering, Chang Jung Christian University, Taiwan.

ABSTRACT

The car accidents caused by fatigue driving have been reporting from the news. In order to avoid the accidents mentioned above, we survey some published methods that used to detect fatigue and find that every method has its own specified purposes. Therefore, this research design the system to detect fatigue and alert driver with light weight brainwave detector and smartphone that everyone has for most car drivers.

In this system, the driver wear a light weight head mounted brainwave device and the signal is transmitted to the smartphone.Our algorithm calculates the driver's fatigue index by focus, eyes blink frequency, α-wave, β-wave, δ-wave and θ-wave to judge the driver's condition. The experimental results show that the system can not only remind driverwhen they are actually fatigued but also find the fatigue period by examine historical records. This research can reduce the occurrence of car accident caused by driver's fatigue.

KEYWORDS

Brainwave Detecting,Fatigue Detecting, APP

1. INTRODUCTION

According the report from WHO[1], 3000~4000 people die on the roads every day in the word and tens of millions of people are injured or disabled every year. If there is no more active and positive action, road traffic crashes are predicted to become the seventh cause to die. Traffic Safety at the American Automobile Association announced that the leading four cause for car accident are distracted driver, driver fatigue, drunk driving and aggressive driving [2]. Driver fatigue leads to 100,000 car accidents every year in the United States, the greatest risk time are between the hours of 11 p.m. to 8 a.m. when our circadian rhythms tell our bodies that it's time for sleep. In addition, driving for long time especially to the long distance driving and take drug that makes people sleepy are all the causes to drowsy.

There are many published methods to detect fatigue: for example, analyzing eye movement patterns, face detection image recognition analysis, and detecting the driver's breathing and heart rate.In general, fatigue drivers experience frequent yawning, heavy eyelids, misjudging traffic situations,fluctuating vehicle speed, seeing everything "jump out" on the road, feeling fidgety or

Dhinaharan Nagamalai et al. (Eds) : WIMO, ICAIT, ICDIPV, NC - 2019
pp. 01-11, 2019. © CS & IT-CSCP 2019 DOI: 10.5121/csit.2019.90401

irritable, and daydreamingwhile driving.The technology for detecting fatigue drivinghave been researching to raise the safety of people and car. Some cars equipped with the fatigue detection system. They analyze various parameters, including steering behavior, pedal usage, and vehicle acceleration, to automatically assess the driver's driving behavior.If the system finds that the driver may be in a state of insufficient attention, a warning light from the coffee cup will be issued to remind the driver to stop for a while. Some cars accumulate the driving times to remind the driver to recover his attention. Most of the detection system judge the state of the driver by his external behaviors. In this paper, we detect the brainwaves of the driver and analyze the signal it outputs and the eye blink frequency toacquire current mental state of the driver. The fatigue index is displayed on the mobile phone. If it exceeds the alarm threshold for more than 5 seconds, it will alert the driver by sounding alarm. At the same time, the system establishes a database to store the data after brainwave analysis to provide users with a history for querying, to know when they are prone to fatigue, and to avoid driving during periods of fatigue, so as to reduce the risk of accidents.

First of all, this research compares the existing fatigue-related methods. Japan, Australia, and Spain all have research on detecting fatigue. Then, we survey several commercially available brainwave meters and compare them. The comparison aspects includes cost, accuracy, ease of carrying (mobility), and ease of operation to comprehensive evaluation to select the proper brainwave meter instrument that meets the requirements.

Japanese eyewear manufacturer JIN published a glasses product JINS MEME on May 13, 2014 [3]. This product has an eyeball detection sensor that can correct the posture of the body and head, fatigue during work, and sleepiness detection. JIN glasses can measure the eight directions of the eyeball by using the electrooculography sensing technology. The potential difference caused by changes in the eyeball and the movement of the eye in all directions can be detected and calculated. This determines the direction of movement of the line of sight and other information, and deeper human behavior can be analyzed by this information to assist in all kinds of things in life. The weight of this glasses is about 40 grams. A little heavier than the glasses that most people wear. Not all users have the habit of wearing this kind of glasses.

A Seeing Machines company in Canberra, Australia, designed and developed the Fatigue Monitoring System for mine truck drivers in May 2013 [4]. The size used for the mine truck driver is so large that it can easily cause staff to be masked by the vehicle next to him. This system consists of a set of infrared cameras that can be detected even when driving with sunglasses that cover the eyes. It also includes the Functional Movement Screen (FMS) and an image processor that records the duration, frequency, and speed of eyes blink to determine if there is distraction or involuntary fragment sleep. Once the system determines that the mental condition is poor, the chair not only has strong vibrations but also sounds harsh alarms. If the mental condition is not good for the second time, the system will inform the relevant administrators and contact the driver to understand whether they need to rest or not. However, if the driver's eyes cannot be detected by the camera because of occasional bowing his head, the alarm will sound as well.

The Valencia Institute of Biomechanics in Valencia developed the "HARKEN" smart seat belt, which detects the breathing and heartbeat frequency of driving and warns in times of crisis; this equipment consists of three main parts, first the seat belt The heartbeat sensor is followed by a breathing detector near the back of the chair, and finally the signal processing unit "SUP" under the seat, which is responsible for analyzing the data of all electronic detectors [5].Endurance athletes, whose heartbeat is lower than the average person every minute, may make the smart seat belt misjudge.

At the 2014 Consumer Electronics Show (CES) in Las Vegas, Xuan Rui Technology from Taiwan demonstrated a device called U-Wake, a standard human-machine interface wearing device that can detect dangerous driving through the change of brainwaves. The brainwave fatigue detector uses brain-computer interface technology. The degree of user fatigue can be instantly displayed on the mobile phone's APP, and reminds the user to stay awake [6], but the system is very expensive.

We depict various kinds of brainwave-meter instruments in the following. The first one is the traditional headgear device. When performing brainwave measurement in traditional way, peopleshould wear a special headgear as shown in Figure 1 to collect the signal. There are multiple electrode pads in the headgear to contact the scalp, and the scalp should be wet-adhesive. Conductive adhesive is capable to enhance the signal collection effect. In addition, the test site must be manipulated in a specific and non-interfering environment. Due to the complicated environment requirement, it is difficult for drivers to use such kind of device.

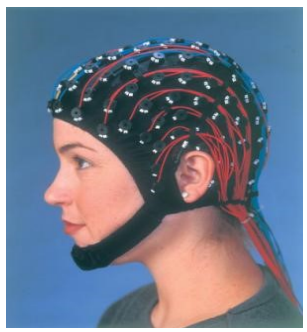

Figure 1. Headgear style brainwave meter [7]

The second brainwave meter is the whole brain covered high density brainwave instrument by dEEG. dEEG is a medical device company that uses the most advanced EEG technology to create a brain-covered high-density brainwave instrument as shown in Figure 2. By using a fast-wearing, non-conductive, mesh-like electrode cap GSN as shown in right side in Figure 2 [8], it provides researchers with the most time-saving, accurate and convenient brainwave recording system. The software has powerful analysis functions such as wave source analysis and ultra-fast head model establishment. In addition, it has 32, 64, 128 or 256 channels to select. The user is required to have the original and complete training to operate the instrument correctly; improper operation will reduce the life of the instrument.

Figure 2. Whole brain covered high density brainwave instrument by dEEG[8]

The third one is Mindwave Mobile Starter Brain Cube as shown in Figure 3 [9]. It is a light weight research-grade EEG headset, which is suitable for the mobile operating system of including iOS and Android and computer operating systems, including Windows and Mac systems as well. The embedded bio-sensor chip can read clear EEG signals, read brainwave signals by non-invasive dry electrodes, filter out nearby noise and electrical interference, and convert the measured signals into Digital signal [10].Measured data obtained through this device, such as raw brainwaves, eSense concentration, processing and output EEG brain power spectrum, blink detection, eSense relaxation and other EEG signal quality analysis even more including detecting whether the device is worn on the head or the problem of poor contact. These data can assist to analyze brainwaves in a relatively simple way and further using the data to make a variety of applicable functionalities. This device owns the pros of easy to carry and high precision of sensing. Moreover; the cost of this equipment is only a small portion of high density research-grade equipment. However, the accuracy can reach 96% of high density research-grade equipment.

Figure 3. Mindwave Mobile Starter Brain Cube

Table 1 shows the comparisons among the three brainwave instruments.

	Traditional headgear style	**Whole brain covered high density style**	**Mobile starter brain cube**
cost	high	high	low
precision	high	high	high
mobility	no	no	yes
operation& manipulation	complicated	professionaltraini ng	easy
conditions for measurements	undisturbed environment	Uncomfortable	unlimited

Table 1 Brainwave meter comparisons

After considering all perspectives, we adopt mobile starter brain cube to be our brainwave meter instrument.
In [10], they conducted a study on "Dynamic Virtual Driving Platform Development and Brain Wave Estimation and Application in Drivers' Psychological Burden" to measure the changes in

mental workload of EEG in a non-invasive manner situation. Based on the simulation of the driving platform, the brainwave is used to analyze and estimate the driver's driving situation. The testing environment is designed to make the driving fatigue easily, and the independent analysis algorithm, primary element analysis, time-frequency analysis and other technologies are used to construct a system to acquire driver's psychological burden so as to estimate the driver's psychological burden by brainwaves. In [11], it conducted a study on driver’s brainwave cognitive response estimation and its application in safe driving, through non-invasively recorded brainwave potential analysis to identify the human brain's response to event stimuli and to estimate the driver's spiritual alert level. Apply this analysis technology to dynamically measure the driver's mental state change, and simultaneously measure the corresponding cognitive, identification, vehicle control and driving behavior changes to maintain the driver's in good spirt mode and prevent driving accidents in driving. In [12], it used EEG components to evaluate the algorithm for detecting fatigue. 52 drivers (36 males and 16 females) were invited to participant this study. Four waves δ, θ, α and β were detected during monotonic driving. It confirmed that the ratio of slow wave to fast wave in EEG activity increased with time, and the results of this study have the significance of detecting fatigue. In [13], it showed that when people feelfatigues, slow wave activity inθand inα bands increased over the entire cortex, but, no significant changes in δactivity. Substantial increases also occurred in fast wave activity. The results claimed that as a person fatigues, the brain loses capacity and slowdown his activity behavior, and that attempts to maintain vigilance levels leading to increasedβwave activity.According to the literature, most of the researches are in the academic field of biological category. They research and find out relationship between the brainwave and fatigue condition. However, no one uses the brainwave data to make a convenient device system for users to measure driving fatigue while driving. In this research, we detect and driver’s fatigue and record the brainwave data in the database. We can not only detect the fatigue condition but also recording the data for long term observation in easy and convenient way.

In this paper, we adopt SQLite to record the data. SQLite is an open source database library, and complies with the standards of ACID-related database. It uses a standard SQL syntax to provide a stand-alone database system that does not require a connecting to environment. It is widely used in various operating systems, embedded systems and browsers. Android supports the SQLite database, so that each application can create its own database, store the data in the SQLite database file, the developers can use the API library provided by Android to access the data in the database for specified applications, including query, add, delete and update standard SQL access syntax, it can also set the version of the database, you can also copy and migrate the database in the new version, so we chose it to build a database.

2. THE PROPOSED METHOD AND SYSTEM ESTABLISHMENT

2.1 Brainwave Detection

The whole system comprises two major stages. The first stage is the brainwave collection by brain cube meter. The brainwave are transmitted to the smartphone to proceed by Bluetooth. Brainwave analysis and recording in the smartphone are the major topics in the second stage. The brainwave acquired by brain cube meter is divided into different bands by Fourier transform. This device has embedded an eSense algorithm to process, that can output the following four data: original brainwave signal, concentration and relaxation indices, brainwave band data (δ, θ, α, β) and blink detection. Physical and psychological conditions represented by various bands of brainwaves can be found easily from web. We will not give you detailed descriptions here. The general properties and frequency ranges of the δ, θ, α, β waves are given in Table 2[14].

Table 2 Brainwaves properties and frequency ranges

Brainwaves		Frequency	Property
Delta (δ)		0.1~3 Hz	Unconscious condition. Occurs during the third phase of non-rapid eye movement sleep.
Theta (θ)		4~7 Hz	Denote subconscious condition There are memories, perceptions and emotions. Affect attitudes, expectations, beliefs, behaviors. The source of creativity and inspiration. Deep sleep, deep meditation. Psychic awareness, strong personal knowledge, strong personality
Alpha (α)	Low range	8~9Hz	A state of mind before going to sleep. Consciousness is gradually drowsy.
	Middle range	9~12Hz	Inspiration, intuition or idea raising. Relaxed but focused
	High range	12~14Hz	Highly alert.
Beta (β)	Low range	12.5~16Hz	Relax but concentrated.
	Middle range	16.5~20Hz	Thinking, dealing with external messages.
	High range	20.5~28Hz	Excitement, anxiety

The brainwave used to represent the body health can be brief depicted as follows. δ wave: rest wave.Deep sleep state will appear generally.θ wave: repair wave. Extremely relaxed, also known as the Buddha brainwave, strong repair. αwave: healthy wave. Relax brainwaves, high immune status, secrete morphine in the brain, and have self-healing ability. β wave: sick wave. Nervous brainwaves, low immunity, easy to get sick.

This research uses the TGAT chip in the Mindwave Mobile Starter brain cube, which is a highly integrated system single-chip brain inductor that can perform analog-to-digital conversion, which can detect abnormalities in poor contact, and filter out abnormal eye movements and 50hz and 60hz AC signal interference in circuit; eSense is an algorithm that is capable of measuring the mental state and collects the user's concentration index and blink strength.In this research, the four bands signal (δ, θ, α, β), concentration index and the blinkstrength are transmitted by Bluetooth to smartphone for further fatigue detection and storing for long term observation.

2.2 Sqlite Database Establishment

In this research, we develop an APP that can be installed in smartphone. APP is a convenient way to any end users to use because it has the advantage of mobility. For the diver, all he has to do is to install the APP in his smartphone and open this APP while driving. Of course, he must wear the brain cube in his head. The following section will give you a brief depict about our SQLite database design in smartphone side. We adopt the Android Studio to implement the system including user interface, Bluetooth connection and SQLite database.

Note that the user must register an account to keep his own data. The historic data can be observer by user to know his own mental condition in every driving. If his friend wants to use this smartphone to raise the driving safety, his friend can register another account.

In this the research, the whole project has six activities named MainActivity, register, Bluetooth, show_result, record and RecordDBHelper. The functions are the main page, registration screen, Bluetooth connection screen, display measurement data screen, history record andlayout respectively.Below figure shows the project structure (Figure 4).

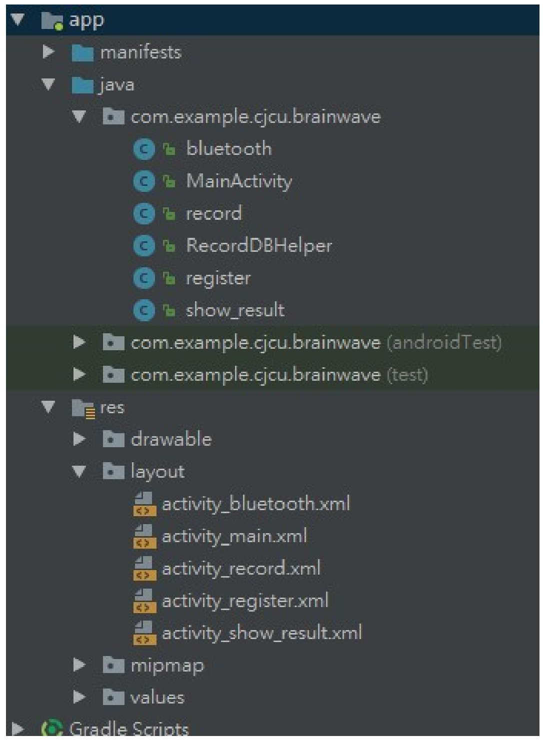

Figure4.Project configuration of this APP

The database created by SQLite is used to store the user's basic data and usage records. The project first creates a database named "brainwaves". The database contains two data tables named "User" and "Data" (Figure 5). "User" table includes _id, name, gender, age, phone, account and password. The "Data" data table is used to store the relevant data of the driver's use process. The nine fields includes _id, date, time, alpha, beta, delta, theta, focus and wink. The primary key is _id. Note that the value ranges of alpha, beta, delta, theta, focus and wink are from 1~100.

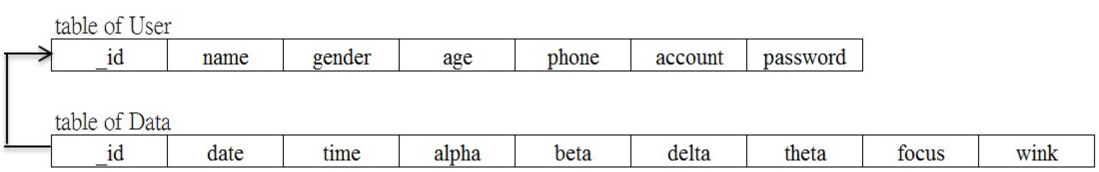

Figure 5.Brainwaves database fields

Use SQLite to add DATABASE named "brainwave". Create a "user" datatable under "brainwave", and in the on Create method, after getting the SQLiteDatabase object, call the execSQL method to create a "user" data table. Using the above method in "brainwave" to create a "data" datatable under the "brainwave"database bycalling the execSQL.

When the user registers, system will confirm whether the data entered by the user are all filled in. The name, gender, age, mobile phone number, account number and password must not be null before the file can be written. Using getWritableDatabase() to construct the database, ContentValues values = new ContentValues() to store the data to be added, and db.insert() to write the data to the database. Figure 6 shows how they work.

```
public long add(String string_name, String string_gender, String string_age,
                String string_phone, String string_account, String string_password) {
    SQLiteDatabase db = getWritableDatabase();
    ContentValues values = new ContentValues();

    if (string_name != null) values.put("name", string_name);
    if (string_gender != null) values.put("gender", string_gender);
    if (string_age != null) values.put("age", string_age);
    if (string_phone != null) values.put("phone", string_phone);
    if (string_account != null) values.put("account", string_account);
    if (string_password != null) values.put("password", string_password);

    long result = db.insert(TABLE_NAME,  nullColumnHack: null, values);

    db.close();
    return result;
}
```

Figure6. Program codes for user registration

2.3 Fatigue Detection Criteria

The Mindwave Mobile Starter brain cube reads the brainwave in the sample rate of 512 Hz. But, we just take one data per second in case occupying too much data storage in smartphone. Then, transmitting the data into smartphone by Bluetooth.After the data is written into the database, the obtained δ, θ, α and β. Note that α and β values that we acquire from brainwave areα_midand β_lowwhichpresenting the awaken state. However; the middle frequency of α wave(α_mid) and the low frequency of β wave(β_low) are the representative values of focus and concentration. While the δ and θ waves denote the unconscious state. Under the brainwave pattern, the purpose of this project is to detect the degree of fatigue by measuring brainwaves under awake conditions. Therefore, the α_midand β_low represent the sobriety and concentration are placed in the denominator, δ and θ represent the unconscious state are placed in the numerator. In addition, and the results of eSense focus and blink valuesare integrated together also to obtain the fatigue index as in Equation 1 after repetitive experiments.

$$Fatigue\_index = \frac{\delta+\theta}{\alpha\_min+\beta\_low} * w + \frac{wink}{focus} \quad (1)$$

Higher fatigue_index denotes the driver's state is drowsy. If the fatigue indices exceedthe threshold value and time, the APP will sound alarm to remind the driver. The w in (1) is set to 10 after experiments.

3. EXPERIMENTAL RESULTS

During the experiments, ten people whose age are from 20 to 50 are invited to participant this research. The driving time was from pm 10:00 to 11:00 because circadian rhythms tell our bodies that it's time for sleep for normal people.Nine people completed the test. Seven of them agreed that it had a remind effect. Two of the testers who are young drivers thought that there was no feeling about this APP. They are accompanied by friends and chatted with them when they drive. One tester claimed that she was not used to reacting with brainwaves device, so she felt uncomfortable and could not finish the test.

Figure7illustrates the fatigue-index curve of a tester who is 50 years old man. He was asked not to turn on the radio in car and driving alone. There are 3600 seconds in one hour recording. Those values that are suddenly abnormally high should be the device error. It could be the error caused by poor contact of the measuring point. The threshold to alert alarm we set in this research is 40. If it exceeds the threshold for more than 5 seconds, it will alert the driver by sounding alarm. It can be observed that he could only concentrate on driving at the early stage.

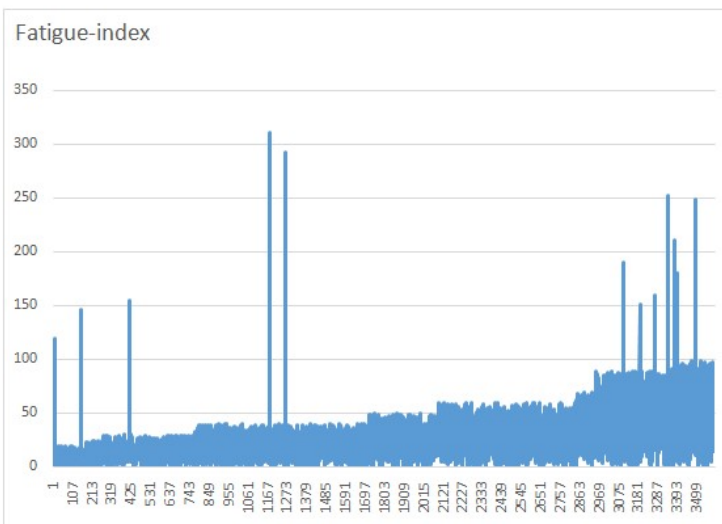

Figure7. Fatigue-index in one hour

4. CONCLUSION AND FUTURE WORK

The crisis of injury caused by fatigue driving is getting more and more serious. Whether is a car dealer or a driver, you should pay attention to this crisis. When big accident occurred, the government institute always review driver's driving regulation, such as forcing the tour bus driver to rest. However; the physical fitness of each driver is different. Even enough resting time, fatigue driving still may occur. Therefore, the most important thing to avoid fatigue driving is immediate detection and reminding.

The brainwave detection driving fatigue system built by the research can remind the driver by sounding alarm when fatigue occurs. Drivers only need to buy a headgear brainwave and smartphone then equipping this APP. The system has two features of low cost and simple operation function. The low cost and simple operation can raise the user's willingness to purchase. We want to encourage drivers to adopt this technology and use it to reduce car accidents caused by fatigue.

As to the further development, the brainwave device and the hat can be integrated on the hardware to facilitate the driver's willingness to use. In addition, the fatigue detection can also be used to monitor students' states during reading at home or learning in classroom. The long term historic record can also be applied to other mental–related issues.

ACKNOWLEDGEMENTS

The authors would like to appreciate the partial support from the Minister of Science & Technology, Taiwan under the project no. 106-2813-C-309-002-E

REFERENCES

[1] World Health Organization. (2018).Road traffic injuries. Available at: https://www.who.int/violence_injury_prevention/road_traffic/en/ [Accessed 10 Nov. 2018].

[2] Collision, W. (2018).The Leading Causes of Car Accidents - Causes and Statistics. Waterdown Collision. Available at: https://www.waterdowncollision.com/blog/safe-driving/leading-causes-of-car-accidents/ [Accessed 10 Nov. 2018].

[3] JINS MEME. (2018).JINS MEME: The world's first wearable eyewear that lets you see yourself. Available at: https://jins-meme.com/en/ [Accessed 10 Nov. 2018].

[4] Seeing Machines. (2018).Driver monitoring technology for automotive, transport & logistics industries. Available at: https://www.seeingmachines.com/ [Accessed 10 Nov. 2018].

[5] Harken.ibv.org. (2018).Wouldn't you want an alarm to go off if you fall asleep driving?. Available at: http://harken.ibv.org/ [Accessed 10 Nov. 2018].

[6] Digital Trends. (2018).U-Wake | Wearable brainwave sensor alerts fatigued drivers | Digital Trends. Available at: https://www.digitaltrends.com/cars/u-wake-wearable-brainwave-sensor/ [Accessed 11 Nov. 2018].

[7] Evolving Science. (2017).Monitoring the Brain Outside the Lab. Evolving Science. Available at: https://www.evolving-science.com/bioengineering-brain-computer-interfaces/monitoring-brain-outside-lab-00129 [Accessed 11 Nov. 2018].

[8] Nutronic Techtronic Co. (2018).dEEG whole brain covered high density brain wave. Available at: http://nutronicltd.com/?deeg%E5%85%A8%E8%85%A6%E8%A6%86%E8%93%8B%E5%BC%8F%E9%AB%98%E5%AF%86%E5%BA%A6%E8%85%A6%E6%B3%A2%E5%84%80,177 [Accessed 11 Nov. 2018].

[9] NeuroKky. (2018).EEG Headsets | NeuroSky Store. Available at: https://store.neurosky.com/ [Accessed 12 Nov. 2018].

[10] Teng-Yi Huang,"Development of dynamic VR driving platform and its application on driver's cognitive state estimation,"Master dissertation, Dept. Elect. & Ctrl. Eng., National Chiao Tung Univ., Hsinchu City, Taiwan, 2003.

[11] Ruei-Cheng Wu, "EEG-Based Assessment of Driver Cognitive Responses and Its Application to Driving Safety," Ph.D. dissertation, Dept. Elect. & Ctrl. Eng., National Chiao Tung Univ., Hsinchu City, Taiwan, 2005.

[12] Jap, B. T., Lal, S., Fischer, P., & Bekiaris, E., (2009)"Using EEG spectral components to assess algorithms for detecting fatigue", Expert Systems with Applications,Vol. 36, No. 2, pp2352-2359.

[13] Craig, A., Tran, Y., Wijesuriya, N., & Nguyen, H., (2012)"Regional brain wave activity changes associated with fatigue", Psychophysiology, Vol 49, No 4,pp574-582.

[14] Wikipedia. (2018).Brainwave - Wikipedia, the free encyclopaedia. Available at: https://zh.m.wikipedia.org/zh-tw/%E8%85%A6%E6%B3%A2 [Accessed 12 Nov. 2018].

AUTHORS

Yung Gi Wu. He received Ph. D. degree from the Institute of Electrical Engineering. National Cheng Kung University. Tainan, Taiwan, 2000. He is now a professor with the Department of Computer Science & Information Engineering. Chang Jung Christian University,Tainan city, Taiwan. His research fields includes data compression, optimization, information retrieval, digital signal processing.

Jwu Jenq Chen was born in Tainan County in Taiwan. He obtained a MS degree from the Graduate Institute of computer science, Ohio University in U.S.A., 1996 and then received a Ph.D. from the Graduate School of Business and Operations Management, Chang Jung Christian University in Taiwan.He had worked as technician and supervisor on computer system for 13 years. At this time, he is anAssociate Professor at the department of Computer Science and Information Engineering at the Chang Jung Christian University,Tainan, Taiwan. Hisresearch fields includes management information system and website design.

Rui Hsin Wang She received the bachelor degree from the Department of Computer Science and Information Engineering at the Chang Jung Christian University in Tainan, Taiwan, 2017. She is now a student in the Institute of Information Engineering. National Chung Hsing University, Taichung, Taiwan.Her research fields includes digital signal processing and mobile computing.