THE REAL TIME MONITORING OF CAR DRIVER'S FATIGUE SYSTEM

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ABSTRACT

This paper is devoted to developing a biomedical engineering application, an IOT-based system which can instantly detect drivers' fatigue level and their physiological condition. Drivers' fatigue level can be estimated by monitoring their real-time bio-data, such as Electrocardiography (ECG), Photoplethysmogram (PPG), blood pressure and blood oxygen saturation. Furthermore, with cloud database, this monitoring system will be fully constructed, Internet of Things (IOT) connects drivers with monitoring platform, and finally it achieves the purpose of improving public transport safety.

1. INTRODUCTION

For the past years, with the development of IOT, many kinds of sensor have prevailed in human's daily life. The global market of wisdom family in 2015 has reached 48.5 billion US dollars, and it is expected to reach 71 billion US dollars in 2018. However, for the transportation, many automotive electronics applications these days are just for passive protection, like airbag and seat belt. Actually, they cannot prevent beforehand. On the other hand, for drivers' active protection, such like active physiological detection, still has not been developed so well.

According to the recent reports in Taiwan, like Dielianhua travel agency's tour bus caused an accident in February this year, happened in the National Road on the 5th South Harbor Road Interchange, resulting in 33 dead and 11 injured people. After the police investigation, the main reason led to this serious accident was drowsy driving. For the issue of fatigue driving, especially for the public transportation, it generally adopts two ways to reduce accidents, manipulating driving time and detecting fatigue by face-image tracking. However, these two means cannot directly and truly monitor drivers' physiological state. To improve public transport safety, it needs a more powerful monitoring system, which will pay attention to drivers' condition at any time. This paper is devoted to the research on biomedical engineering with IOT, and developing a real-time monitoring system, to observe drivers' bio-data such as ECG, PPG, blood pressure and blood oxygen saturation. Moreover, this system will connect to cloud server through mobile internet, return drivers' bio-data back to monitor center, to secure each drivers' and passengers' safety.

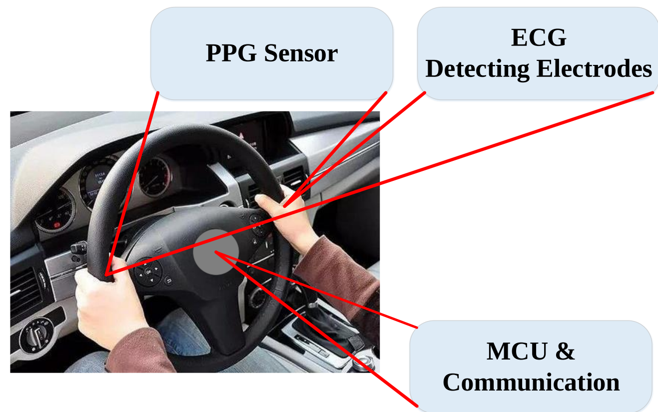

Fig. 1. Scenario of the real time monitoring of car driver's system.

This real-time monitoring system is built up with the front end for fetching bio-signal as well as the back end for cloud computing and internet service. The front end on steering wheel consists of tiny sensors and high-resolution analog sensing circuit with tiny Printed Circuit Board (PCB) design. The back end includes self-developed APP for data transmission via mobile internet to cloud database and user interface on website for monitor center. With this system, it can monitor drivers at any time.

2. DESIGN OF PROPOSED BIOMEDICAL SYSTEM

2.1. System overview

Briefly, the real time monitoring of car driver's fatigue system is a system provide supervisors to monitor all drivers' situation. Therefore, supervisors can pay attention to those exhausted drivers and prevent accidents. As shown in Fig. 1, this work is a steering wheel, combining with hardware and some software design.

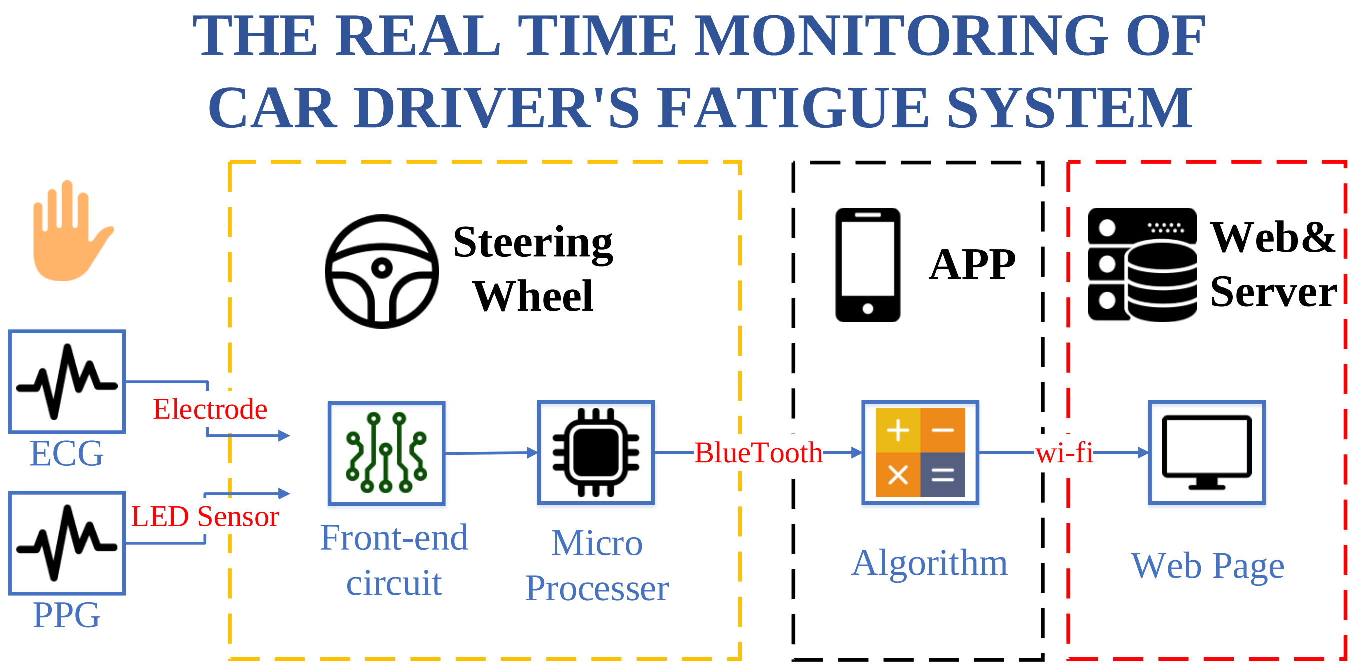

Fig. 2. System block of wireless bio-signal acquisition and application.

The structure of the product should not cause any obstacle to driver's activity. So that, drivers can drive as if there is no sensor there. The message platform of system can realize "remote two-way communication of physical and mental state", so supervisor can know driver's situation.

The mode of communication system on this work connect to internet by several step, as shown in Fig. 2. First, sensor will give instructions to conduct the measurement periodically, and pass the bio-signal to smart phone by Bluetooth. Secondly, smart phone will execute algorithm in self-made APP—"Driver MaMa", then deliver result to database server. Finally, supervisor website will fetch drivers' data and check their physical and mental state. If the result is irregular, supervisor website will launch the warning signals to inform drivers by application, so that drivers can take a break to avoid accidents.

Furthermore, the function of Global Positioning System (GPS) positioning on smart phone can check whether driver is on the right way or not. Moreover, the APP will record supervisor's phone number, so drivers can communicate with supervisor whenever they want in emergency.

2.2. SENSOR DESIGN

In order to detect drivers' bio-data for fatigue detection, this paper build the front-end design on a steering wheel, shown as Fig. 3. The PPG sensor consists of optics semiconductor called SFH-7060, a micro photo sensor. Drivers' thumbs can be placed without obstruction, which makes the PPG signal can be steadily fetched.

Besides, for the ECG signal, two copper slices are set on the outskirt of steering wheel. These two copper slices act as electrodes, detecting the ECG data from drivers' palms, shown as Fig. 3. Through this design made up of sensors, sensing circuits and steering wheel, the system will be able to obtain drivers' real-time bio-data while they are driving, without any disturbance.

2.3. FRONT-END CIRCUIT STRUCTURE

According to the fact that SFH-7060 transfers the photocurrent, it needs a trans-impedance amplifier to convert the photocurrent into the voltage. After that, it can start to deal with the voltage by the front-end circuit design.

Fig. 4 shows the front-end circuit design. The Front-end circuit is going to deal with bio-signals from sensors. Because noise in surrounding is unavoidable, our team design a band-pass filter that combine a low pass and a high pass filter. Instrumental amplifier makes input signal more recognizable, which enhance the accuracy of algorithm's result.

2.4. APP—"Driver MaMa" SYSTEM STRUCTURE

The APP system structure consists of two parts: for users and for data. In term of users, as shown in Fig. 5, Driver MaMa includes Login system and Detect system. For the Login system, drivers have to login first, in order to connect with server. Therefore, supervisors can start to get the information of drivers and both of them can communicate with each other.

For the Detect system, it has built-in timer that could launch bio-signal, position and driving time to server.

After measuring, the current results with the former data are compared in order to see whether something wrong with drivers. If something wrong happens, supervisor will inform message to drivers by mobile internet to ensure the immediate monitoring. Despite nothing irregular happens, it will still upload the updated data to server, so that the supervisor could check the information on this big database.

On the other hand, with the system block from data side, as shown in Fig. 6, data is passed by Bluetooth from Microcontroller Unit (MCU). Then, APP will decode the Bluetooth data according to Bluetooth Low Energy (BLE) protocol. Since MCU combines ECG and PPG in order to improve efficiency and accuracy, APP should return to the original signal. Given fetching the original ECG and PPG, APP can make mathematical calculation of bio-state accordingly. In this step, data combine with user interface to show on the smartphone. APP will pack all bio-signal to server to make further function. Supervisor can inform drivers whenever emergency happens, so driver can do. Remote two-way communication then is being realized.

2.5. ALGORITHM

In order to obtain the features for fatigue detection from ECG and PPG signal, the main algorithm is peak detection. When this algorithm is applied for ECG signal, R-peak value is acquired, which can infer drivers' heartrate and Low Frequency (LF) / High Frequency (HF) for Heart Rate Variability (HRV). A lot of survey indicate that HF is related to parasympathetic nerve whereas LF is related to sympathetic nerve. So we can get bio-state from the ratio of HF and LF of HRV. Besides, for PPG signal, by fetching the staggered signal from red Light-Emitting Diode (LED) and infrared LED, it can estimate drivers' blood oxygen saturation [1]. Furthermore, pulse transit time (PTT), a feature that strongly links to blood pressure calculation [2], can be acquired by simultaneously detecting drivers' ECG peak and PPG. According to the time varience, it can turn PPT to the blood pressure. Fig. 7 illustrates a process of how the system obtain those features from ECG and PPG signal.

2.6. WEBPAGE

In this project, the monitoring webpage is developed to help monitoring all the bus drivers to prevent the fatigue driving. As the system structure shown in Fig. 8, before going to the web design, it needs to build an apache server for web programming. In this work, the apache server gets the information and data of the drivers from the smart phone app by php every thirty seconds. Then the server will immediately transfer them to the database called Mysql on the server. According to the database and the server, the web can get the information and data instantly. As the server gets the data, the monitoring webpage would renew the positions of drivers on google map and the fatigue ranking automatically, and users can click the markers on the map to monitor the single driver or watch the fatigue raking. Therefore, it is easily for people to know all the drivers' physical conditions on webpage.

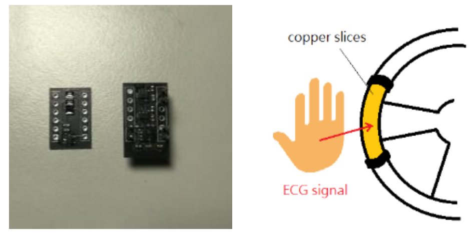

Fig. 3. Structure of sensors.

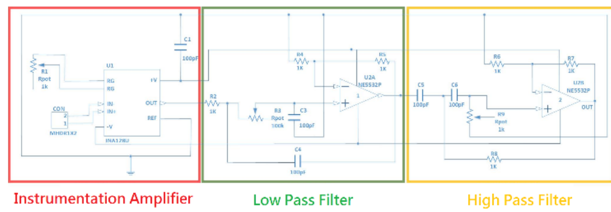

Fig. 4. Front-end circuit structure.

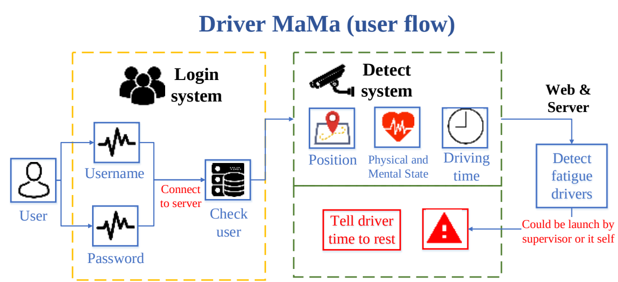

Fig. 5. System block of user side.

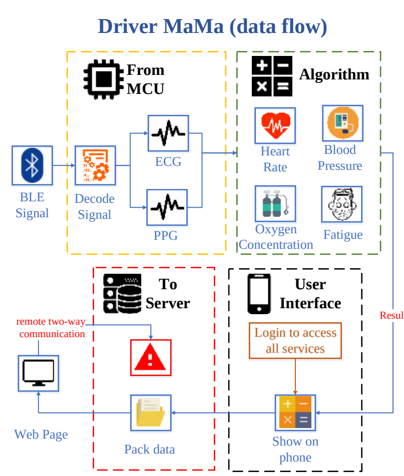

Fig. 6. System block of data side.

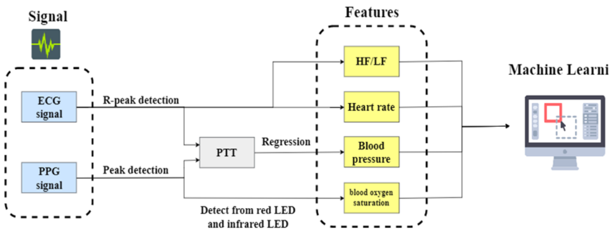

Fig. 7. System block of algorithm

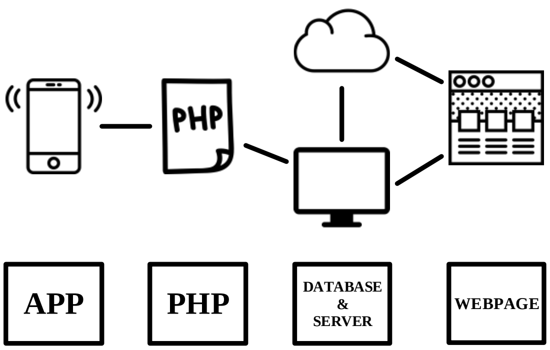

Fig. 8. System block of web.

Fig. 9. Steering wheel design overview.

Fig. 10. PCB Layout overview.

4. PRATICAL OVERVIEW

4.1. STEERING WHEEL & CIRCUIT OVERVIEW

Fig. 9 shows the finished steering wheel. It is composed of PPG sensor, the opto-semiconductor, and ECG sensor, the copper electrodes. Through this design, human's PPG signal and ECG signal can be obtained easily.

4.2. PCB LAYOUT OVERVIEW

In order to minimize the front-end circuit, PCB layout of ECG and PPG signals shown in Fig. 10 is indispensable. Moreover, in our design, the diameter of the two circuits is only 2.522 centimeter.

4.3. SIGNALS OVERVIEW

In Fig. 11 and Fig. 12, they show the waveform of the signals received from this work. Each of them shows clear waveform and peak values, making algorithms easy to do the further calculation for fatigue features.

4.4. APP OVERVIEW

APP user interface shows driver's information and state, as shown in Fig. 13. Through this interface, driver's name, their destination, and driving time could be clearly identified. Besides, driver's physical states also show on this APP, in order to let the users know their true bio-condition.

4.5. WEBPAGE OVERVIEW

Fig. 14 is the interface of our webpage. On the right of the webpage is the ranking list of each driver's fatigue state. The most tired drivers will be shown on the top in this column, so the supervisor can easily put their full attention to those drivers. On the left of this website shows the Google map, in where system marks each driver's current location by clicking the driver id on the ranking list.

5. COMPARATION

5.1. EXISTING PRODUCT

Currently, there are some product about detecting driver's fatigue. Most of them focus on the external features of drivers, such as the facial images. Therefore, they cannot look into the deep level of human body. However, in this work, this design collects a variety of signals, and it has more accuracy to predict fatigue of drivers.

6. EXPERIMENTAL DESIGN FOR HIGH SCHOOL STUDENTS

In this project, senior high school students share their idea about this system, and share their experience in daily life, giving us some inspiration for more application. We, the college students, taught them some EE knowledge in this system, such as our circuit's concept and algorithm's principles, as shown in Fig. 15. After a lot of discussion, we have learnt a lot from each other.

Senior high school students play an important role in our team. They find the best angle and distance between PPG sensors and LEDs; they also acquire the knowledge of our circuit's main function, and rebuild the front-end circuit on the breadboard, as shown in Fig. 16. Besides, they have learnt how to implement some simple algorithm on Arduino for getting fatigue features.

7. MILESTONE

So far, hardware and user interface are well-prepared, and the algorithm is almost done, as shown in Fig. 17. All we have to do is to collect more and more data, to test our algorithm's correctness; also, it needs to increase diversity of test subjects, in order to train the fatigue model and make it more reliable.

8. REFERENCES

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[2]. [3] Ramakrishna Mukkamala, Jin-Oh Hahn, Omer T. Inan, Lalit K. Mestha, Chang-Sei Kim, Hakan Töreyin and Survi Kyal, "Towards Ubiquitous Blood Pressure Monitoring via Pulse Transit Time: Theory and Practice", August, 2015

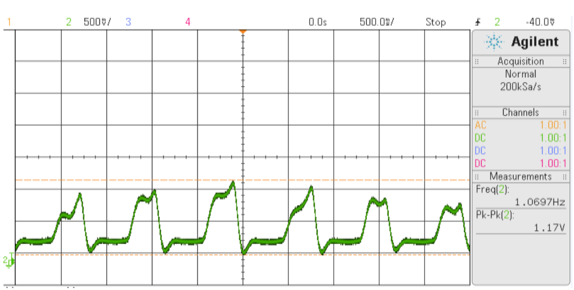

Fig. 11. The waveform of PPG signal.

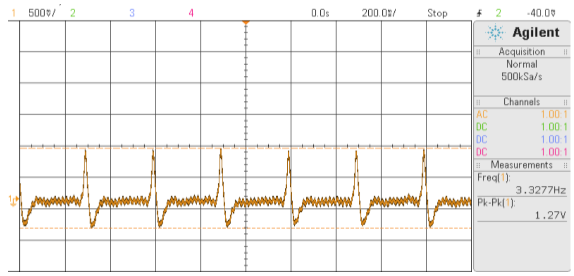

Fig. 12. The waveform of ECG signal.

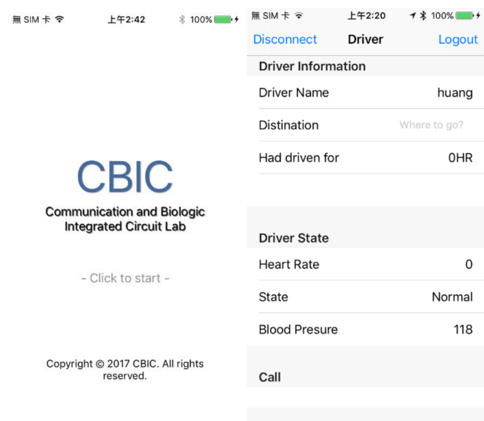

Fig. 13. APP overview.

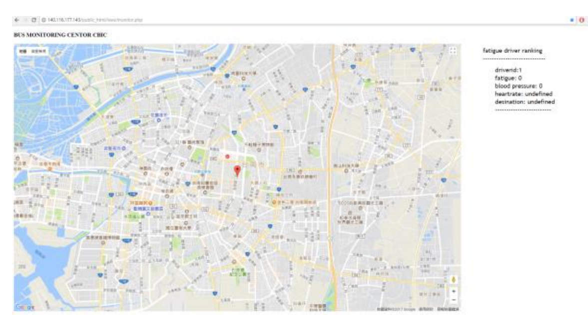

Fig. 14. webpage overview.

Fig. 15.Discussion with the high school students

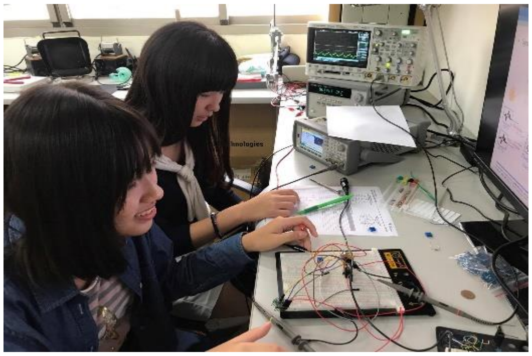

Fig. 16. High school students rebuild the circuits on breadboards

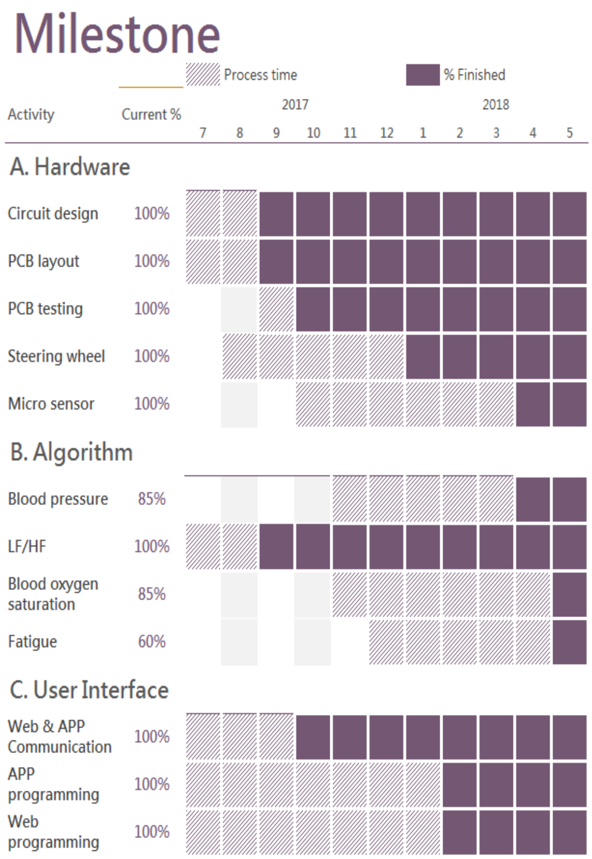

Fig. 17. Milestone of each subtasks in the research