Drowsiness Detection System Using Heartbeat Rate in Android-based Handheld Devices

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Abstract—**Driving is a common activity in every person's daily life which is important to make sure it is safe and secure. Although many rules have been implemented to manage the traffic, accident such as collision are still happened. One of contributed factor to this is drowsy driving. We developed a drowsiness detection system using the information of ECG signal to minimalize the risk of the accident. ECG signal acquired from a sensor, which then transferred via Bluetooth to android device to calculated power ratio by applying hamming window and FFT technique. As the ratio decreasing, the system will activate the alarm which indicate the driver is drowsy.**

Keywords-drowsiness detection; heartbeat rate; power ratio; android; HR sensor

I. INTRODUCTION

A number of traffic collision or car crash occurs frequently and become the hotspot of people care. There are many factors contribute to the risk of the accident, such as road environment, vehicle design, and driver's behavior. The driver's behavior factor seems to be the most common reason contributing the accident such as drowsiness while driving alone for a long trip. Drowsiness driving denote a situation when the driver is in a state of mental and physically fatigue, which included decreasing mental alertness and a sensation of weariness and reduction in eye scanning behavior. A severely drowsy driver will exhibit extended incompetence to safely perform a driving maneuver, be unaware of the vehicle's turning radius, perform driving maneuver under the incorrect assumption, experience eye lid closures and repeated yawning. When the driver impaired by fatigue, driving ability, behaviors, proficiencies and decisions are adversely affected and, in this situation, the risk of the accident such as car crash that may result in property damage, severe injury, of even death is highly increase due to the fact that sleepy drivers fail to take proper decision prior to a collision [1].

Drowsy driving is a serious issue in our society not only because it affects those who are driving while drowsy, but because it puts all other road users in danger. This drowsy driving has been a major cause behind car accidents, and expose the driver to much higher crash risk compared to driving while in alert [2]. Therefore, the use of assisting systems that monitor a driver's level of vigilance is crucial to prevent road accident. These systems should then alert the driver in case of drowsiness or inattention.

There are many ways to detect the drowsiness of the person. With the help of the brain waves, pulse rate, heart rate, respiration etc., it will be able to find whether the person is feeling drowsy or not. Based on the changes that occur in these physiological measurements, it is possible to detect the drowsiness. Other ways of detecting drowsiness include focusing on the visual behaviors for any changes in the facial features like face, head and eye [3]. In the paper proposed by Picot, drowsiness detection system has been implemented using the brain and visual activity [4]. There is an electroencephalographic channel that is used to monitor the activities of the brain for the drowsiness detection. Shan and Bowlds used a pulse wave sensor to detect the drowsiness [5]. A face detection method based on morphology technique was proposed by Han et al [6]. This method was based on the eye analogue segmentation since the eyes and the eyebrows are the relatively stable features in the human face. The located eye-analogue will be used to search for the potential face regions with a geometrical combination of eye, nose and mouth. A trained back propagation (BP) neural network will get all potential face images and verify the face location. As people become drowsy, their blinking patterns change. Sigary proposed a method of hypo-vigilance detection by processing of the eye region and without an explicit eye detection stage [7]. For drowsiness determination, the percentage of eye closure and eyelid distance changes over the time.

in order to overcome the issues and achieve the objective for an assisting system to detect drowsiness for drivers, a workable system that detects the drowsiness of a person (e.g. driver) based on heart rate was developed. By implementing some calculation method to the heartbeat rate, it can be told whether a person is drowsy or not. When a person goes from awake state to drowsy state, the heartbeat rate tends to decrease as well. The heartbeat rate signal from a sensor (i-Mami-HRM2 in Fig. 1) is retrieved which is placed on the driver's chest to transfer the data to an android based device (e.g. an Android smartphone) via Bluetooth technology in order to process and visualize the signal in real time. The signal is then processed by applying signal processing techniques: Hamming Window and FFT (Fast Fourier

978-1-4673-8940-2/16 $31.00 © 2016 IEEE
DOI 10.1109/ICMIP.2016.23

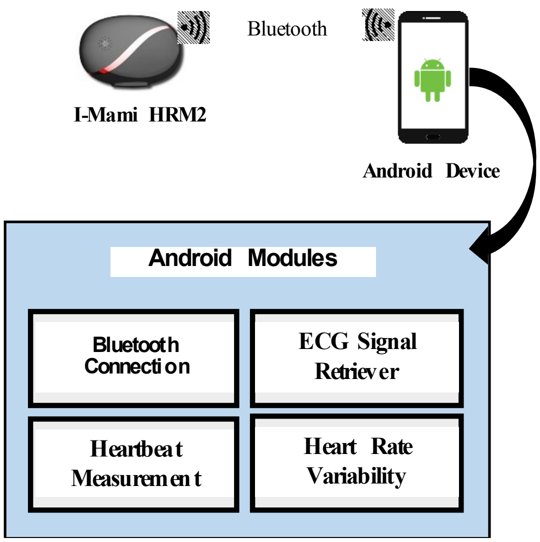

Figure 1. System Architecture.

Transform). The power spectrum of the signal from low frequency (LF) to high frequency (HF) is obtained and is used as key parameter to determine whether a person is drowsy. The LF/HF power ratio will show a decreasing trends as the driver goes from awake state into drowsy state. As the system detect the drowsiness, an alerting signal such as alarm on the Android device will be activated to alert the driver.

The rest of the paper is organized as follows. Section II describes how the drowsiness detection system is implemented. Then in Section III, the results and discussions of the implemented system are explained in detail and finally a conclusion is drawn in Section IV.

II. Implementation of Drowsiness Detection System

A. System Architecture

Fig. 1 presents the architecture of the system. It consists of four modules: (1) Bluetooth connection, (2) heartbeat measurement, (3) ECG signal retriever, and (4) heart rate variability including some variables based on the normal to normal heartbeat intervals analysis.

1) Bluetooth Communication: Bluetooth technology has been applied so that the sensor device (I-Mami HRM2) and android device are able to communicate each other. I-Mami HRM2 sensor is a small, lightweight device that is worn across the chest. It sense the heart rate in a frequency of 250H_z. Initially, the sensor and the android device need to be paired. When heartbeats sense by the sensor, the signals are transferred to the android device via Bluetooth communication.

2) ECG for Drowsiness Detection: Electrocardiography is a process of recording the electrical activity of the heart over a period of time. It is a measure of the change in potential of the order of 1mV produced as a result of the electrical stimulation during the cardiac cycle. This signal is retrieved from the sensor I-Mami HRM2, sent to the smart phone and displayed as ECG signals in the phone. This ECG signal is drawn in the screen of the phone as shown in Fig. 2.

3) Heart Rate Measurement: In the heart rate module, the heart rate of a person is calculated for every one minute with the average value and the maximum value are also calculated. This information then will be displayed on the android device. Fig. 3 is an illustration.

4) Heart Rate Variability: The phenomenon of variation in the time interval between heartbeats is called Heart Rate Variability. In time domain analysis, variables based on the normal to normal (NN) heartbeat intervals are analysed. These variables are useful to find any heart related issues. These variables are explained below and shown on Fig. 4 [8]:

- SDNN (The standard deviation of normal to normal intervals): Variables that calculated over a 24-hour periods.
- SDANN (The standard deviation of the average normal to normal intervals): Calculated over a short period, usually every 5 minutes. It is therefore a measure of changes in heart rate due to cycles longer than 5 minutes.
- NN50 (Number of pairs of adjacent NN intervals differing by more than 50ms in the entire recording): It is the number of intervals differences between the successive normal to normal intervals greater than 50ms.
- PNN50 (NN50 count divided by the total number of all NN intervals): It is the proportion derived by dividing NN50 with the total number of NN intervals.
- AVNN: Average of all NN intervals.

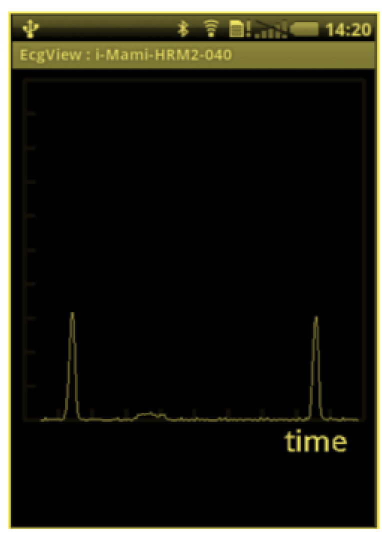

Figure 2. ECG signal displayed on the screen.

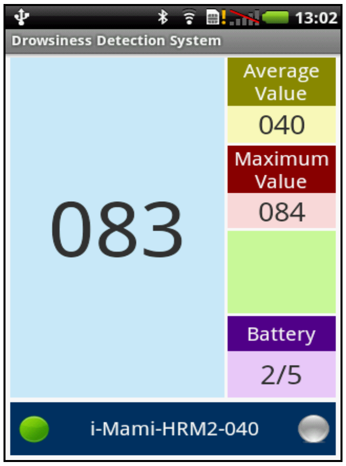

Figure 3. Heartbeat rate and other values.

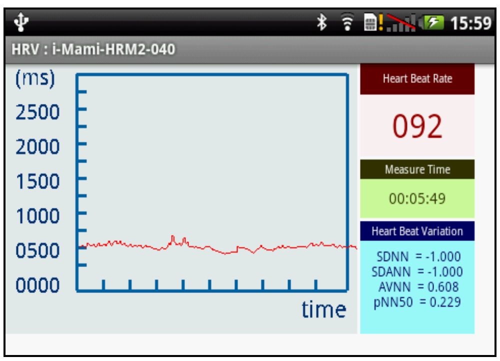

Figure 4. Heart rate variability.

B. Implementations

In this drowsiness detection system, various signal processing techniques is applied to measure ECG signal. Fig. 5 explains the various technique and processing flow implemented to get the power ratio. After the ECG signal is obtained, the sampling rate is reduced by 50 in order to reduce the processing complexity of the signals. Further for every 512 samples of data, hamming window and FFT techniques are applied to calculate the power spectral. From the FFT, the power ratio is calculated for a maximal value of 3 (max_count), if the power ratio is found decreasing then the person is alerted and the process is repeated from collecting the next 512 samples.

C. Signal Processing Techniques

1) Decimation: Decimation is a process of reducing the sample rate. This is usually done to reduce the data of the size of the data. In decimation, the sampling rate is reduced from f_s to f_s/M by discarding M-1 samples for every M samples in original sequence [9]. The sampling rate of the sensor is 250 Hz that resulted in a very large amount of data to be processed. To lessen the quantity of data and speed of process, the sampling rate is thus reduced to 50 Hz, which means 5 (250/50) samples per second and this decimation was done using a low pass filter.

2) Window Function: A window function is applied to the measured signals in order to process large data set for analysis purpose. As our research is to analyse ECG signal, the window function selected is called Hamming window function [10]. The mathematical expression for Hamming Window is shown in (1),

$$W(n)=0.54-0.46\cos(2\pi n/N-1) \qquad (1)$$

where n is the n^{th} sample and N is the total number of samples. The samples in this research are those measured data. In the calculation, the ECG raw data will be multiplied with the Hamming window function before doing the FFT in order to reduce the spectral leakage.

3) Fast Fourier Transform: To determine the spectrum of the signal, fast Fourier transform is used to convert the signal from its time domain into the frequency domain in order. FFT is an efficient algorithm which is still one of the most used algorithms in digital signal processing. The breakthrough of the Cooley-Tukey FFT comes from the fact that it brings the computing complexity down to an order of $NLog2N$, where N is the number of samples [11]. The radix 2 decimation in time (DIT) FFT is adopted to analyse ECG signals to find their power spectrum. Here, the radix 2 resembles the number of samples (N) which must be an integral power of two. Further, it works on complex input data where the real and imaginary parts are stored in two separate arrays. Also, the Radix-2 DIT divides a DFT of size N into two interleaved DFTs of size $N/2$ with each recursive stage as in (2),

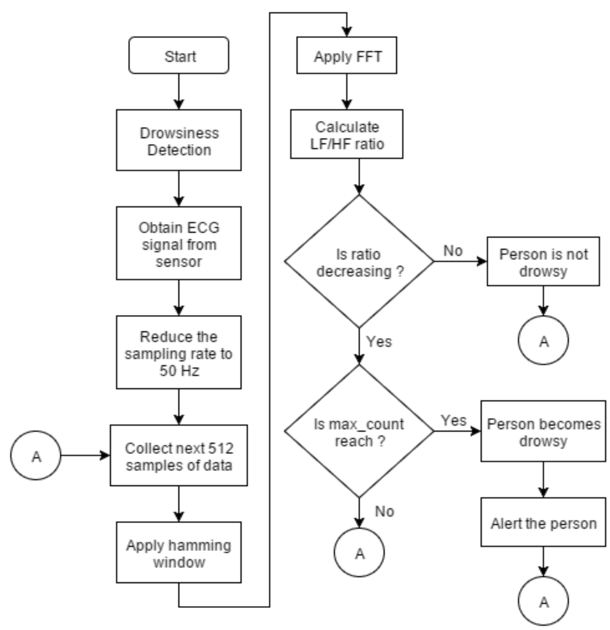

Figure 5. Drowsiness detection flow.

$$X_k = \sum_{n=0}^{N-1} x_n e^{\frac{2\pi i}{N} nk} \quad (2)$$

where k is an integer ranging from 0 to N-1.

III. Results and Discussions

To validate and evaluate the drowsiness detection system, the experiment is done by testing the system on male and female when both are in awake state as well as in asleep state. By applying FFT, the power ratio is calculated every 1 minute and tracked for a total of 120 minutes. The data were collected for each person under test from she or he is ready to sleep to fall asleep. The reason that a long period was observed and measured is that the authors would like to know the change of power ratio for a person from awake state to asleep state. Four male and four females were tested for many times, and the resulted were obtained by taking the average of individual for male and female respectively.

For each spectrum, the LF/HF power ratio is the concern. The low frequency (LF) component (0.04~0.15 Hz) reflects both para-sympathetically and sympathetically mediated for HR and the high frequency (HF) component (0.15~0.4 Hz) reflects para-sympathetically mediated for HR. That is, the LF part is the total spectral power of all NN intervals between 0.04 and 0.15 Hz and HF part is the total spectral power of all NN intervals between 0.15 and 0.4 Hz. In addition, the LF/HF ratio for HR also reflects the cardiac sympathovagal balance or adjustment.

Fig. 6 and Fig. 7 show the average power ratio for male and female when they are in awake state to asleep state, respectively. The graph clearly indicates that when the person is getting asleep, the LF/HF ratio is decreasing in both cases. The power ratios are tending to stable after 100 minutes from the measurements. The value corresponding to the time is the assumed power ratio for a person getting drowsiness.

The mean value of power ratio of all the averages from awake state and asleep state is also presented in the graph. From these mean values it is clear that the difference in the heart rate variability for both male and female does not differ by a large number during their awake and asleep stages. The value 0.240668 represent the mean value for awake state and 0.162554 represents the mean value for sleep state. From these two values it is clear that the level of drowsiness falls within this range.

From the Fig. 6 and Fig. 7, it is observed that all the power ratio in awake states are above 0.18. This implied that when the person goes to drowsy state, the value of the LF/HF ratio will start to decrease from 0.17. If the ratio reaches 0.17 and start to decrease after this value for a total count of 3 (measured for consecutive three times in Fig. 5), then the alarm is set to alert the drowsy driver.

IV. Conclussion

In this research, the purpose is to detect a person's drowsiness by analyzing his ECG signals. Various modules were implemented to detect the heartbeats. The signal that obtained from the sensor are transferred to an Android Device which then processed. The system extracts the information from the ECG signals and analyzed power spectrum by FFT. The power on the low and high frequency component were measured from the power spectral density. Then LF/HF power ratio was calculated for every minute during monitoring.

From the result, the HRV analysis from two-hours heart rate time series shows that LF/HF ratio had a decreasing trend when a person fall asleep or feeling drowsy. According to the frequency analysis of heart rate time series, the decreasing trend of ratio is resulting from the increase of power in the HF range or the decrease of power in the LF range when people fall asleep. When the decreasing trend is identified below 0.17 for total count 3 and continuously decrease, the system will invoke an alarm to alert the driver.

The results showed that the determination of power spectrum density (PSD) of electrocardiogram signal can then be an effective and simple method to detect the drowsiness. Also, the proposed system can be applied to the test of sleep disorder of a person as an assistance on analyzing the causes of somnipathy.

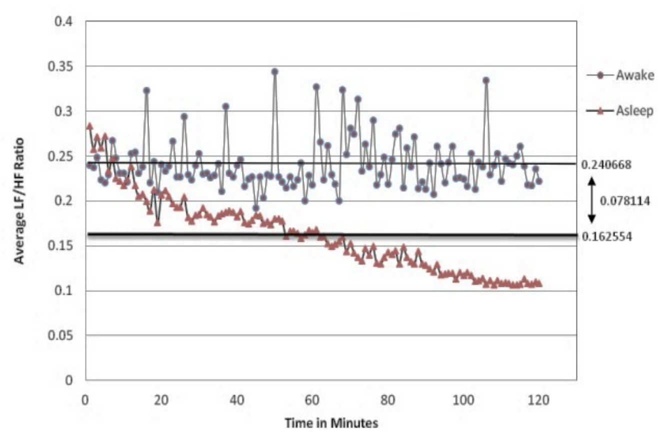

Figure 6. Average power ratio for male from awake to asleep.

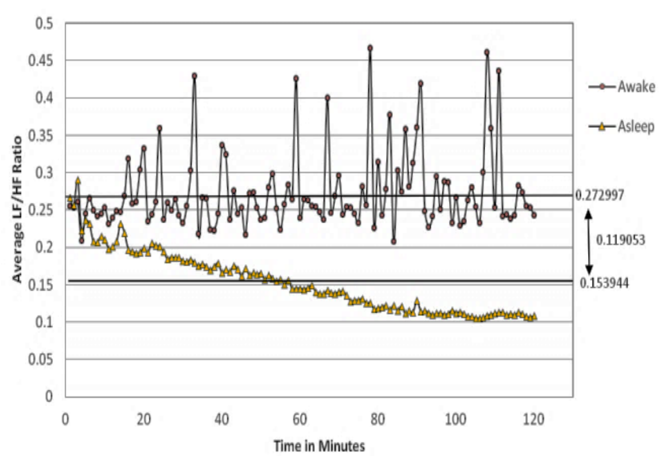

Figure 7. Average power ratio for female from awake to asleep.

ACKNOWLEDGMENT

This research is supported by Ministry of Science and Technology, Taiwan, R.O.C. Project Number: MOST 104-2221-E-027-041.

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