MONITORING DROWSINESS BASED ON ELECTROENCEPHALOGRAM ANALYSIS
วิธีตรวจสอบความง่วงจากคลื่นไฟฟ้าสมอง

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บทคัดย่อ

จากหลักฐานความสูญเสียที่เกิดขึ้นทุกปี อุบัติเหตุบนถนนยังคงเป็นปัญหาสังคมมายาวนาน ความอ่อนล้า และความง่วงของคนขับรถเป็นปัจจัยสำคัญที่ทำให้มีอัตราการเสียชีวิตสูงเพราะความสามารถในการรับรู้ของคนขับรถลดลง ดังนั้นการตรวจสอบความง่วงเป็นการป้องกันการเกิดอุบัติเหตุที่สำคัญวิธีหนึ่ง งานวิจัยนี้จึงนำเสนอวิธีการตรวจสอบความง่วงจากคลื่นไฟฟ้าสมองโดยใช้ตัวกรองสัญญาณดิจิตัลแบบ Infinite Impulse Response (IIR) การคำนวณค่าพลังงานสเปกตรัม (power spectra) ของคลื่นไฟฟ้าสมอง และระบุสถานะของสัญญาณจากค่าพลังงานดังกล่าว ผลการทดลองแสดงให้เห็นว่าวิธีนี้สามารถระบุระดับการรับรู้ระหว่างหลับและตื่นได้แม่นยำ

คำสำคัญ: ความง่วง, คลื่นไฟฟ้าสมอง, พลังงานสเปกตรัม, ตัวกรองสัญญาณดิจิตัลแบบ Infinite Impluse Response (IIR)

Abstract

Road accidents have been a social concern for several decades as evident in the large amount of losses and damages every year. Drivers' fatigue and drowsiness is one of major reasons which yield high fatality rate because of the decline in the driver's consciousness. Therefore, detecting driver's drowsiness is of prime importance in preventing such accidents. This reseach proposes an electroencephalogram-based drowsiness estimation algorithm that combines IIR filtering, electroencephalogram (EEG) power spectra analysis and the classification based on optimal threshold. The results demonstrated that it is feasible to accurately determine the subjects' alertness.

Keywords: Drowsiness, Electroencephalogram (EEG), Power spectra analysis, Infinite Impulse Response (IIR) filter

Introduction

Driving accidents has remained a social concern worldwide as evident in the report from United Nations Economic Commission for Europe (UNECE) [1] revealing an estimated 164,677 persons killed on the roads in the ECE region and 6,118,844 persons seriously injured in 1997. Komchadleuk newspaper on Sunday 27 September, 2009 [2] disclosed the statistics on road accidents in Thailand ranked in the top fifth of world wide accidents. The losses and damages accumulated for last 10 years have been estimated to more than 2 billon baht which is accounted to 2.8 percent of total GDP. In addition, on the 5th October 2009, in Thailand there was a train accident due to drowsiness and cost more than 100 million baht. As a result, preventing such accidents caused by drowsiness is a major focus of efforts in the field of active safety research [3-7].

A number of methods used to detect driving vigilance changes can be categorized into two main approaches. The first approach focuses on physical changes during fatigue, such as the inclination of the driver's head and sagging posture and decline in gripping force on steering wheel. The second approach focuses on measuring physiological changes of drivers, such as eye activity measures, heart beat rate, skin electric potential, and particularly, electroencephalographic activities as a means of detecting the cognitive states [8]. Electroencephalogram (EEG) is a record of brain activity and obtained from electrodes placed on the scalp above the various regions of the brain. Electrodes on specific regions monitor electrical activity associated with its functioning neurons. The common periodic rhythms recorded in the EEG are alpha (8-13 Hz), beta (13-30 Hz), delta (1-5 Hz) and theta (4-8 Hz) [9].

This project proposes an algorithm to determine subject's binary state of alertness and sleep based on EEG power spectrum analysis. The four common rhythms are compared to obtain the best drowsiness's estimation. Besides, input data length and number of fast Fourier transform taken into account for the least error detection.

Aims

To estimate a person's drowsiness based on EEG power spectrum analysis.

Materials and methods

The materials used involve Head Skin Scrub: Nutret scrub, Electrode gel: 10/20 electrode gel, Electroencephalogram (EEG), Computer System, Simulation program: Bus simulator program, Game Controller: Genius Speed Wheel 3 MT, and Shampoo: Johnson baby shampoo. Considering the Method, there are some important steps as follows:

1. Preparation before EEG recording

Subjects voluntarily sign ethical agreement and are required to prepare as the following steps before conducting the experiment [10].

1.1 Stop taking certain medicines such as sedatives and tranquilizers, muscle relaxants, sleep aids or medicines used to treat seizers. These medicines can affect brain's usual electrical activity and cause abnormal test results.

1.2 Do not eat or drink foods that have caffeine such as coffee, tea, cola and chocolate for 8 hours before the test.

1.3 Hair must be clean and free of sprays, oils, creams and lotions. Shampoo hair with Johnson baby shampoo and rinse with clear water the evening before the test. Do not put any hair conditioner or oil on after shampooing.

2. Electrode Placement and Recording

Sixteen electrodes are placed on the scalp based on 10-20 system of electrode placement shown in Table 1. Each subject will be experiment for approximately 30 minutes. EEG waves are recorded at sampling rate of 200 Hz and filtered to obtained signal with frequency ranging from 1 to 70 Hz. Three infinite impulse responses (IIR) filtens were applied on EEG signal accordingly as follow: Filter 1: IIR low pass filter with order of 2 and cutoff frequency of 70 Hz, Filter 2: IIR high pass filter with order of 4 and cutoff frequency of 1 Hz. Filter 3: IIR Band Reject filter with order of 5 and cutoff frequency I of 48 Hz and cutoff frequency II of 52 Hz.

Table 1: List of EEG channels

Channel	Channel	Channel	Channel
1: Fp1-F7	5: Fp2-F8	9: Fp1-F3	13: Fp2-F4
2: F7-T3	6: F8-T4	10: F3-C3	14: F4-C4
3: T3-T5	7: T4-T6	11: C3-P3	15: C4-P4
4: T5-O1	8: T6-O2	12: P3-O1	16: P4-O2

3. Feature extraction

Firstly spectrogram is used to observe the distribution of frequency of the spectrum to the power of the overall signal. Spectrogram computes the Fourier transform of the auto-correlation function which represents the relationship of long and short-term correlation within the signal itself.

The four common rhythms - alpha, beta, delta and theta are extracted from the original brain wave in accordance with their frequency range by IIR filter. The original signal and the four filtered rhythms are further computed to obtain the relative maximum amplitude of power spectrum. In addition, input data length of 60, 90 and 120 seconds, number of fast Fourier transform which must be the next power of two between 512 to 2048 points and all the EEG channels are also considered to acquire the most accurate results.

4. Classification

The normal and drowsy groups are pre-known and categorized by the relative maximum power spectrum. Brain wave of normal active subjects is likely to contain high magnitude of power spectrum and vice versa for drowsy subjects. The two groups are determined by optimal threshold which is computed to produce the least error detection.

Results

1. Electrode Placement and Recording

Sixteen electrodes are placed on the skull as shown in Figure 1. A drowsy subject is required to sleep on the bed while an alert subject drives a bus simulator. The mark of sleep state begins when the subject snores till the invigilator tells the subject to wake up.

Figure 1: EEG Recording at HRH Princess Maha Chakri Sirindhorn Medical Centre

2. Feature extraction

Spectrogram of sleep and alert subjects is displayed in Figure 2 and 3. It is observed that the frequency distribution in a sleep subject is lower in magnitude than that in an active subject. Also, high intensity distribute over large frequency range in an active subject. The example of the power spectrum is plotted in Figure 4 which its maximum amplitude will be used to classify itself.

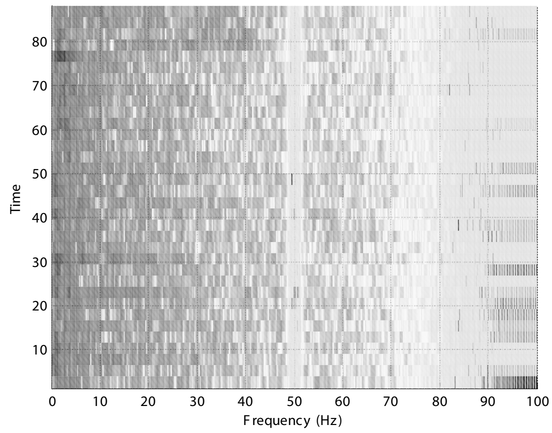

Figure 2: Spectrogram of sleep subject

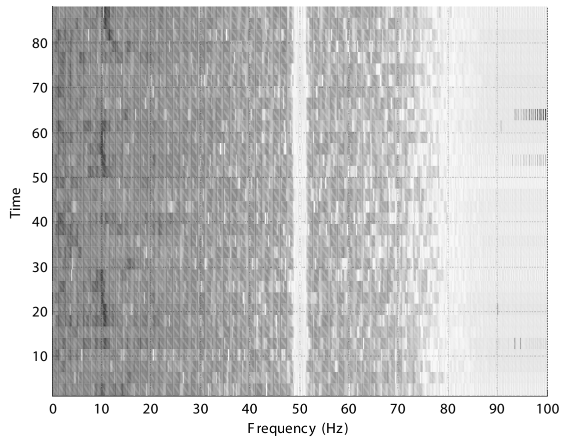

Figure 3: Spectrogram of an active subject

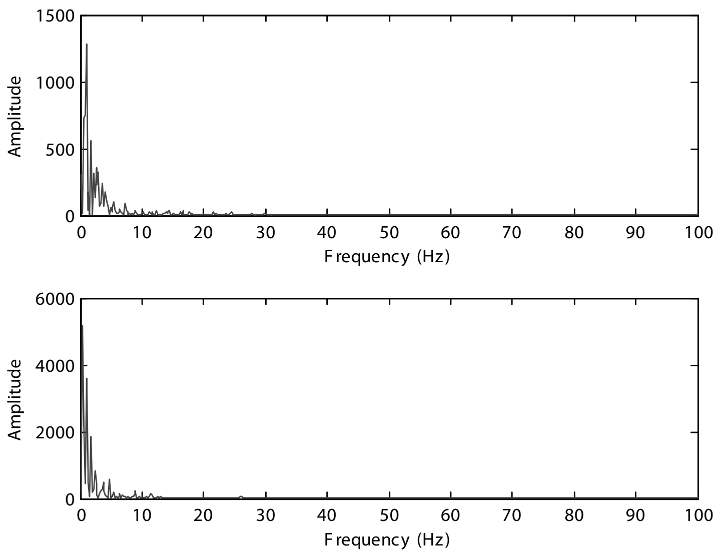

Figure 4: Power spectrum of original brain wave of sleep (up) and alert (bottom)

3. Classification

Power spectrum is computed with various input data length of 60, 90 and 120 seconds. At specific input signal, the number of FFT (Nfft) is also varied from 512 to 2048 points. To classify between active and sleep brain wave, threshold is computed to obtain the optimal value yielding the least error detection. From Figure 5, the least error detection is acquired from data length of 90 seconds and Nfft of 1024 points. These parameters are applied to original signal and four common rhythms as shown in Figure 6. As a result, beta wave yields the minimum error detection at threshold of 0.0705.

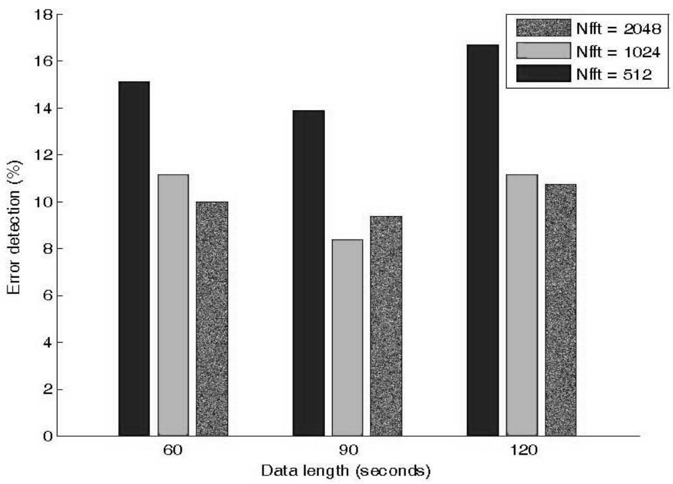

Figure 5: Error detection when vary original input data length and Nfft

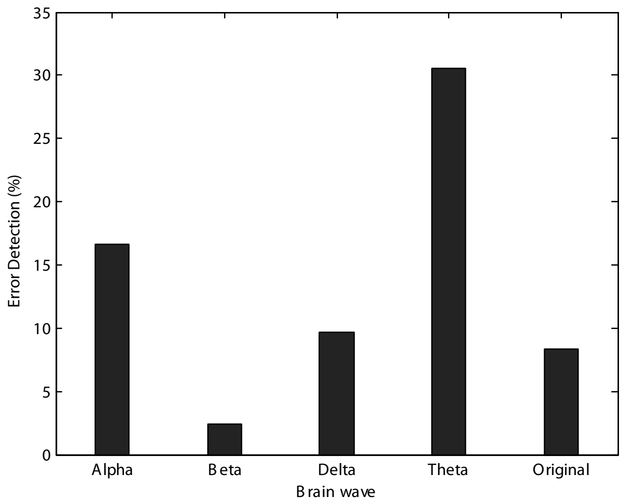

Figure 6: Error detection from different rhythms

Conclusions and Discussion

Total number of dataset of normal active and drowsy group is 69 and 13 sets respectively. Based on the least error detection of beta wave analysis from channel Fp1-F7, NFFT of 1024 points and input data length of 90 seconds, it yields the number of false positive and false negative of 0 and 2 respectively. Therefore sensitivity and specificity is 84.62% and 100%.

In this project we classify subjects into two groups which are active and sleep status which may be the limitation of this study. However, the level of consciousness can be divided further. Therefore we expect to monitor and estimate this stratification based on signal processing of EEG for future work.

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