IDENTIFICATION OF DIFFERENT FREQUENCY SOUND RESPONSE FROM EEG SIGNAL

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ABSTRACT

In recent years, a lot of research has been carried out to study on human brain response when listening to different kinds of music, as well as different quality of sound waves. High frequency component and low frequency component, either audible or inaudible, contained in a sound wave is proven to as a cognitive factor to human acoustic system and can be shown through human brain signal. Electroencephalographic (EEG) technology has enabled effective measurement of human brain activity, as functional and physiological changes within the brain may be registered by EEG signals. In this project, electrical activity of human brain due to sound waves of different frequency is studied based on EEG signals. Collection of EEG signals from 5 healthy adults is done using Neurofax EEG-9100 device. Subjects are exposed to different frequency sound waves of 40 Hz, 500 Hz, 5000 Hz and 15000 Hz. The EEG signals are then processed using signal processing algorithms in Matlab, i.e. Principle Component Analysis, Discrete Wavelet Transform, Fast Fourier Transform etc. Useful information is extracted from the processing of EEG signal, and algorithm to identify the different frequency sound response from the EEG signals is developed using artificial intelligent techniques, i.e. neural network, fuzzy logic, and adaptive neuro-fuzzy system. The result from this project has shown that the characteristics of EEG signals differ with respect to different frequency of sound waves, and yet different frequency sound response from EEG signal can be identified by using suitable A.I. algorithms.

ABSTRAK

Kajian terhadap tindakbalas otak manusia ketika mendengar muzik dan bunyi yang berlainan jenis dan kualiti telah banyak dijalankan sejak tahun kebelakangan ini. Komponen frekuensi tinggi dan rendah yang terkandung gelombang bunyi, sama ada di dalam had pendengaran manusia, ataupun di luar had pendengaran manusia telah terbukti sebagai satu faktor kognitif terhadap sistem pendengaran manuasia. Fakta ini tertunjuk melalui isyarat otak manusia. Aktiviti otak manusia boleh diukur secara berkesan dengan teknologi Electroencephalograhic (EEG). EEG boleh mengesan perubahan fisiologi dan fungsi yang terkesan di dalam otak manusia. Dalam projek ini, kajian terhadap aktiviti elektrik di dalam otak manusia terhadap bunyi yang berlainan frekuensi dijalankan berdasarkan isyarat EEG. Isyarat EEG daripada 5 subjek yang sihat direkod dengan menggunakan mesin Neurofax EEG-9100. Subjek dikehendaki mendengar gelombang bunyi dengan frekuensi 40 Hz, 500 Hz, 5000 Hz and 15000 Hz semasa experimen dijalankan. Pemprosesan isyarat EEG dijalankan dengan menggunakan modul pemprosesan isyarat yang terkandung dalam perisian Matlab, seperti 'Principle Component Analysis', 'Discrete Wavelet Transform' , 'Fast Fourier Transform' dan sebagainya. Infomasi yang penting boleh diekstrak melalui pemprosesan isyarat EEG. Seterusnya, perisian untuk frekuensi pengesahan daripada isyarat EEG direka dengan menggunakan teknik kecerdikan buatan, seperti rangkaian neural, "fuzzy logic" dan sistem penyesuaian neuro-fuzzy. Keputusan daripada projek ini menunjukkan isyarat EEG mempunyai ciri-ciri yang berbeza terhadap bunyi dengan frekuensi yang berlainan. Akan tetapi, frekuensi pengesahan daripada isyarat EEG secara berkesan dapat dijalankan dengan menggunakan teknik kecerdikan buatan yang sesuai.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Hearing is one of the human five senses. The sense of hearing is performed by human auditory system: vibrations are detected by the ears and transduced into nerve impulses that are perceived by brain, primarily in the temporal lobe of human brain. Ideally, a healthy human can hear sounds within the range of 20 Hz – 20 kHz. Hearing different quality of sound, i.e. loud or soft, high pitch or low pitch, audible or inaudible etc., will have different effects to our brain. The ability to differentiate the quality of a specific sound is due to human brain response to different qualities of sound. The human brain do produces different electrical activity due to the different frequency of sound waves.

One of the common methods to measure human brain activity is by using Electroencephalography (EEG) technology. Electroencephalography (EEG) is an electrical waveform that is recorded from the brain by using electrodes appropriately placed on the head/scalp. To visualize this EEG signal, this signal is amplified and displayed through a computer or other suitable instrument. EEG signal consists of a wave that varies in time, much like a sound signal, or a vibration. As such, it contains a great deal of information that can be used to characterize the EEG signals for clinical and research purposes.

The useful information contained in the raw EEG signal cannot be visualized with just bare eyes. On top of that, raw EEG signals usually contain artifacts that will complicate the analysis of EEG signal. There have been a lot of research work on EEG signal processing, as well as classification of EEG signal. All these methodologies from previous work provide good references for future research and exploration on EEG technology.

1.2 Problem Statement

When listening to sound waves or tones of different frequencies, ranges from 20 – 20 kHz (human hearing range), our brain will react differently and produce EEG signals with different qualities/characteristics. Based on this understanding, ideally we can reverse the process, where if a series of EEG signals are given (the EEG signal is recorded when a subject is listening to sound wave of different frequency), we should be able to identify the frequency of the sound wave.

However, EEG data captured over the scalp usually contain artifacts or noise. These artifacts or noise maybe caused by the instrument or biological response, e.g. eyes movement, certain concentration or distraction etc. In order to analyze and classify the EEG signal correctly, the EEG signals need to be processed, and the artifacts to be filtered. Characteristics of the signals are to be extracted, and classification will be done based on these characteristics or qualities of the EEG signals. The characteristics of these EEG signals may have slight differences as each one of us is a unique entity. Therefore, there is a need for a proper algorithm to identify the different frequency sound response from EEG signal.

1.3 Objectives

The main objective of this project is to develop an algorithm to identify different frequency sound response from EEG signal. Generally, the electrical activity of human brain due to sound waves of different frequency is to be studied based on the EEG signals. Later on, with the understanding on the EEG signals, research on signal processing and artificial intelligent algorithm is to be carried out to identify the suitable signal processing and classification methods for EEG signals. Lastly, an algorithm for classification of EEG signals with respect to different frequency sound response using artificial intelligent techniques is to be developed.

1.4 Scopes of Study

This project involves a series of research work on EEG signal processing and artificial intelligent algorithms in order to develop a software that is capable of performing EEG signal processing for identification of different frequency sound response. Basically, the scope of study can be categorized as below:

1. EEG data collection using EEG machine in Medical Electronic Laboratory in Uninversiti Teknologi Malaysia. Subjects are to be identified to perform the testing, i.e. listening to sound waves of different frequencies (i.e. 40 Hz, 500 Hz, 5000 Hz and 15000 Hz) and EEG data are collected from 4 locations at temporal lobe (T3, T4, T5, T6) using a single electro-cap connected to the electrode board adapter.

2. EEG signal processing. Raw EEG signal is to be filtered for noise and artifact removal. EEG signal in time-domain is to be transformed into frequency domain using suitable signal processing techniques. With proper signal processing, important information can be extracted from the EEG signals, and to be used in the next step.

3. Characterization of EEG signals. The EEG spectrum is observed to fall into different frequency bands, i.e. Delta (< 4 Hz), Theta (4-8 Hz), Alpha (8-13 Hz), Beta (13-30 Hz) and Gamma band (> 30 Hz). With the different characteristic observed from the signal, EEG signals can be classified effectively.

4. Artificial intelligent (A.I.) techniques. Proper classification using A.I. techniques are used to achieve the objective of the study, i.e. to identify different frequency sound response from EEG signal. A.I. technique is simpler and easier to apply for signal with a lot of non-linear components, as compared to conventional modeling approaches.

1.5 Organization of the Report

This report consists of eight chapters with the brief description of each chapter as stated below:

Chapter 1 presents the introduction to this project, includes the background of the project, problem statements, objectives of the project and scopes of the study.

Chapter 2 provides literature reviews from previous research work from other researches on EEG signals on human acoustic system, EEG signal processing techniques, and some well-known A.I. technique for EEG related research.

Chapter 3 discusses about the methodology applied in this project, including the project planning and schedule, design and implementation workflow, hardware and software involved in this project.

Chapter 4 describes the procedure of EEG data collection. This chapter discuss about the experiment setup and EEG data recording procedure in this project.

Chapter 5 describes the methodology used for EEG data processing, starting from EEG noise removal, followed by feature extraction from EEG signals, and lastly some preliminary analysis on the EEG signals.

Chapter 6 describes the implementation of EEG identification algorithm using A.I. techniques like artificial neural network, fuzzy system and adaptive neuro-fuzzy inference system.

Chapter 7 discusses the result from the identification algorithm using various A.I. techniques. The performance of each algorithm is compared against each other.

Chapter 8 concludes the overall work done in this project. Shortcoming of the system designed in this project is discussed, and recommendation for future work is discussed as well.

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