DETECTION OF WAVE V USING CONTINUOUS WAVELET TRANSFORM AND INSTANSTANEOUS ENERGY FOR HEARING LOSS

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Praise to Allah the Almighty

Thanks to my beloved mother, father and lovely wife

For humanity, hope to be more submitted, pious and to the Creator do we return

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ABSTRACT

Hearing screening is an essential test to detect hearing ability of someone. A good hearing ability is absolutely necessary for a normal speech development. In cases with pronounced hearing loss even no speech ability will develop at all causing serious communication problems and impaired intellectual and emotional development. Auditory brainstem response is a well known method that has been used on detection of hearing problem. An alternative method was also introduced in this thesis in detecting the hearing loss problem. Evoked potentials are used because they can indicate problem along nerve pathways that are too subtle to show up during neurologic examination or to be noticed by the person. This description may not be visible on magnetic resonance imaging test. This study proposes methods of identifying hearing loss based on continuous wavelet transforms (CWT) and instantaneous energy (IE). Study showed that the IE performed better than the CWT with the sensitivity of 0.88 and specificity of 0.81 compared to the CWT with the sensitivity of 0.63 and specificity of 0.83. Significance of the results is 0.42.This experiments result can be used as a basis to improve methods of detection hearing loss.

ABSTRAK

Ujian pendengaran merupakan satu ujian yang penting bagi mengesan keupayaan pendengaran seseorang. Keupayaan pendengaran yang baik sangat perlu untuk pembangunan pertuturan yang normal. Dalam kes - kes kehilangan pendengaran, keupayaan pertuturan juga tidak dapat dibangunkan yang mana menyebabkan masalah komunikasi yang serius dan juga ketidakseimbangan pembangunan intelektual dan emosi. Auditori refleks batang otak merupakan kaedah yang sering kali digunakan bagi mengesan masalah pendengaran. Keupayaan rangsang digunakan kerana ia boleh mengesan masalah sepanjang lorongan saraf yang terlalu halus untuk dilihat semasa pemeriksaan neurologi atau dikesan oleh seseorang dengan mata kasar. Masalah sepanjang lorongan saraf ini mungkin tidak dapat dilihat melalui pengimejan resonans magnetik. Dalam kajian ini kaedah mengenalpasti gangguan pendengaran berdasarkan transformasi gelombang selanjar (CWT) dan tenaga serta merta (IE) telah dicadangkan. Penyelidikan menunjukkan bahawa IE lebih baik daripada CWT dengan tahap kepekaan 0.88 dan kespesifikan 0.81 berbanding CWT dengan tahap kepekaan 0.63 dan kespesifikan 0.83. Keputusan ekperimen ini boleh digunakan sebagai asas untuk meningkatkan kaedah pengesanan kehilangan pendengaran.

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LIST OF SYMBOLS

dBnHL	-	Decibel normal hearing level
μV	-	microvolt
Ag-AgCl	-	Argentum-argentum cloride
k	-	kilo
Ω	-	Ohm
A1	-	Mastoid left
A2	-	Mastoid right
Cz	-	Vertex
Hz	-	Hertz
Fz	-	Forehead
dB	-	Decibel
μs	-	microsecond
dB SL	-	Decibel sensation level
dB peSPL	-	Decibel peak equivalent sound pressure level
ms	-	millisecond
s	-	second
τ	-	translation
ψ	-	wavelet transform
$\int$	-	integral
$\sqrt{}$	-	Square root

t	-	time
s	-	scale
$\sum$	-	summation

LIST OF ABBREVIATIONS

ABR	-	Auditory brainstem response
AC	-	Alternating current
AEP	-	Auditory evoked potential
ASSR	-	Auditory steady state responses
BAEP	-	Brainstem auditory evoked potentials
CD	-	Compact disk
CNR	-	Contrast to noise ratio
CT	-	Computed tomography
CWT	-	Continuous wavelet transform
DPOAE	-	Distortion product otoacoustic emissions
DSP		Digital signal processing
DWT	-	Discrete wavelet transform
ECG	-	Electrocardiography
EEG	-	Electroencephalography
EMG	-	Electromyography
EMI		Electro-magnetic interferences
EOAE	-	Evoked otoacoustic emissions
EP	-	Evoked potentials
ERP	-	Event related potential
FFT	-	Fast Fourier transform

gPAH	-	Guger programmable attenuator headphone buffer
gTec	-	Guger Technology
gUSBamp	-	Guger USB amplifier
g.Zcheck	-	Guger impedance check
ICU	-	Intensive care units
IE	-	Instantaneous energy
LED	-	Light emmiting diode
MRI	-	Magnetic resonance imaging
NICU	-	Neonatal intensive care units
OAE	-	Otoacoustic emissions
OAFCCD	-	Ontario association for families of children with communication disorders
OR	-	Operating rooms
SEP	-	Somatosensory evoked potentials
TEOAE	-	Transient evoked otoacoustic emissions
USB	-	Universal serial bus
UTM	-	Universiti Teknologi Malaysia
VEP	-	Visual evoked potentials
WACFM	-	Weighted averaging based on criterion function minimization

CHAPTER 1

INTRODUCTION

1.1 Introduction

Hearing screening is an essential test to detect hearing ability of someone. It is one of the most important recommendations in modern pediatric audiology. A good hearing ability is absolutely necessary for a normal speech development. In cases with pronounced hearing loss even no speech ability will develop at all causing serious communication problems and impaired intellectual and emotional development. Many methods have been used as hearing screening tools. One of the popular screening tools is auditory brainstem response (ABR) machine (Satoshi *et al.,* 2003; Bradley and Wilson, 2004). There are also some other hearing screening tools such as transient evoked otoacoustic emissions (TEOAE), distortion product otoacoustic emissions (DPOAE), pure tone audiometry, tympanometry and auditory steady state responses (ASSR) (Satoshi *et al.,* 2003; McWilliams, 2008; Swanepoel *et al.,* 2004).

Nowadays, hearing screening becomes important. There are needs to implement hearing screening in every hospital. However, the time consuming problem for the existing equipment have caused difficulties to implement hearing screening. Recently, many researchers try to come out with new approach to improve the hearing screening system.

1.2 Problem Statement

Several types of hearing screening programs have been established so far to detect the hearing loss as early as possible (Helfand *et al.,* 2001; Delb, 2002; Delb, 2003). The technical methods used in these programs include otoacoustic emissions (OAE, sound responses that are emitted from the ear) and auditory evoked responses or ABR (responses in the electroencephalography that are evoked by an auditory stimulus).

There are two types of OAE screening techniques, TEOAE and DPOAE (Helfand *et al.* 2001; Delb, 2003; Plinkert and Delb, 2001; Delb *et al.,* 1999; Delb *et al.,* 2004). TEOAE are generated in response to clicks while DPOAE are a response to tones. Both stimuli are presented via lightweight ear canal probes. A microphone picks up the signal, and multiple responses are averaged to get a reproducible waveform. This test can be carried out at the bedside and a pass or fail response is recorded. TEOAE measurements are more commonly used for screening whereas DPOAE are still a subject of research (Delb *et al.,* 1999). The absence of TEOAE indicates that the inner ear is not responding appropriately to sound. TEOAE can be used for a hearing check but they do not allow for a quantification of the hearing loss (Delb, 2003).

The ABR is an electrophysiological response in the electroencephalography generated in the brainstem in response to auditory signals such as clicks or chirps. The stimulus is delivered via earphones or an inserted ear probe, and scalp electrodes are used to obtain the signals. Detection of wave V in the ABR measurements is the most reliable objective diagnosis and quantification of hearing loss (Delb, 2003; Wicke *et al.,* 1978; Woodworth *et al.,* 1983; Mason and Adams, 1984; Peters, 1986; Shangkai and Loew, 1986). This method has a higher specificity as the TEOAE measurement and it can also be used for the detection of the hearing threshold, i.e., the quantification of the hearing loss.

However, due to a poor signal-to-noise ratio, 2000 to 4000 sweeps have to be averaged to obtain a meaningful, visually noticeable signal at a particular stimulation level (the exact number depends on the number of artifacts produced). As such large-scale averaged signals are used in the conventional visual analysis; they are also commonly used in computational scheme, although, for a machine other data representations might be more appropriate (Strauss *et al.*, 2004). Using the currently available devices, this takes approximately 2 to 4 minutes to get the result for one stimulation level, e.g., (Meier *et al.*, 2004) where it was not possible to obtain a reliable response in less than even 4 to 5 minutes. This measurement time requires a state of spontaneous sleep or strong sedation. Therefore, the needs to design a faster screening tool become important.

1.3 Objectives of the Research

The main objective of this research is to use signal processing theory to improve the detection of wave V with reduced number of sweeps. In order to achieve the main objective, several sub-objectives are addressed in this thesis as following:

(1) To apply averaging technique in detecting the wave V signal for abnormalities of hearing impairment.

(2) To apply Fourier transforms to analyze the power spectrum on different sweeps or clicks.

(3) To apply continuous wavelet transforms to detect abnormalities of hearing impairment.

(4) To apply instantaneous energy to detect abnormalities of hearing impairment.

1.4 Scope of Research

The scopes of research are limited to the following issues:

- The research is focus on real ABR signal. The simulated signal is not included in this research. Real ABR signal is original ABR signal recorded from patient, while simulated signal is generated by machine known as ABR signal simulator. Analysis and features extraction based on simulated signal are not reliable. Real signal are largely interfered by many factors such as background noise, patients' movements and age.

- The real ABR signals are collected at out-patient clinic at Pusat Kesihatan Universiti Teknologi Malaysia (UTM) and Pusat Kejuruteraan Bioperubatan, Fakulti Bioperubatan dan Sains Kesihatan, UTM.

- The patients' ages are from eight to thirty years old.

- This research is limited to data analysis based on ipsilateral recording.

- This research focused on the averaging technique, continuous wavelet transforms (CWT) and instantaneous energy (IE) to detect abnormalities of hearing impairment and this research used Fourier transform to analyze the power spectrum on different sweeps or clicks.

1.5 Contribution of the Thesis

In this research, there are two different techniques have been developed based on signal analysis techniques which are IE and CWT used as marker in order to detect wave V. The main contributions of this research is to see whether signal processing theory can be an alternative approach to determine hearing impairment compared to the traditional approach of averaging. The CWT and IE approach in this thesis do provide a primary result to further the work in this area.

1.6 Outline of the Thesis

This thesis is organized into six chapters. The current chapter describes the introduction of this research, the background and problems of this research as well as the objectives, scopes and contributions of this research.

Chapter 2 describes literature review on hearing loss and hearing screening. Various types of hearing loss are described; conductive hearing loss and sensorineural hearing loss. The hearing loss factors are also discussed in this chapter. Various types of hearing screening tools and the digital signal processing techniques used on analyzing auditory signals are discussed.

Chapter 3 describes an overview of human ear, auditory nervous system, human brain and the evoked potential. The human ear from the outer to the inner ear had been discussed. The discussion also covered sound propagation from the outer ear to the brain. The evoked potential is also discussed in this chapter.

Chapter 4 describes the methodology of the research in detail. The features of the subjects and environment are described in this chapter. This chapter covered the discussion on the electrodes configurations that had been used in this study. The stimulus, hardware as well as data acquisition are also discussed in this chapter.

Chapter 5 describes the analysis techniques of the research in detail. The most popular method in ABR research, the averaging technique is discussed in this chapter. The technique is used to extract the ABR wave signal from the recorded brain signal. The wave V detection techniques that had been used in this research are also discussed.

Chapter 6 delivers the results of the experiments carried out. Several experiments were carried out, based on averaging, continuous wavelet transform and instantaneous energy techniques to find out a way to establish fast detection of wave V in order to test hearing problems.

Chapter 7, the final chapter, summaries the research findings and some suggestions for future work which might be useful for further development and improvement are written in this chapter.