MODIFIED CYCLIC SHIFT TREE DENOISING TECHNIQUE WITH FEWER NUMBER OF SWEEP FOR WAVE V DETECTION

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Praise to Allah the Almighty

Thanks to my beloved mother and father

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

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ABSTRACT

Nowadays, in developing countries Newborn Hearing Screening (NHS) has become one of the most important recommendations in modern pediatric audiology due to the important of early detection for newborn as the first six month of age are the critical period for learning communication. Auditory Brainstem Response (ABR) is an electrophysiological response in the electroencephalography generated in the brainstem in response to the acoustical stimulus. The conventional method used previously was accurate, but it is time consuming especially with the presence of noise interference. The objective of this research is to reduce screening time by implementing enhanced signal processing method and also to reduce the influence of noise interference. This thesis applies Wavelet Kalman Filter (WKF), Cyclic Shift Tree Denoising (CSTD) and Modified Cyclic Shift Tree Denoising (MCSTD) to overcome these problems. The modified approach MSCTD is a modification from CSTD where it is a combination of the wavelet, KF and CSTD. The modified approach was compared to the averaging, WKF and CSTD to analyze an effective wavelet method for denoising that can give the rapid and accurate extraction of ABRs. Results show that the MCSTD outperform the other methods and giving the highest SNR value and able to detect wave V until reduce sweeps number of 512 and 1024 respectively for chirp and click stimulus.

ABSTRAK

Pada masa kini, pemeriksaan pendengaran bayi yang baru lahir telah menjadi salah satu perkara penting dalam bidang audiologi pediatrik moden di negara-negara membangun berikutan pentingnya pengesanan awal untuk bayi yang baru lahir. Tempoh enam bulan pertama umur adalah tempoh yang kritikal bagi pembelajaran komunikasi. ABR adalah tindak balas elektrofisiologi dalam *electroencephalography* yang dijana dalam otak sebagai tindak balas kepada rangsangan akustik. Kaedah konvensional yang digunakan sebelum ini adalah tepat tetapi ianya memerlukan masa yang lama terutamanya dengan kehadiran gangguan bunyi. Objektif kajian ini adalah untuk mengurangkan masa pemeriksaan dengan meningkatkan kaedah pemprosesan isyarat dan juga mengurangkan pengaruh gangguan bunyi. Tesis ini menggunakan *Wavelet Kalman Filter (WKF), Cyclic Shift Tree Denoising (CSTD)* dan *Modified Cyclic Shift Tree Denoising (MCSTD)* untuk mengatasi masalah ini dan mengesan gelombang V dalam bilangan kitaran yang lebih sedikit. Kaedah baru MCSTD ini merupakan pengubahsuaian daripada kaedah CSTD dimana ianya adalah gabungan antara *Wavelet*, KF dan CSTD. Kaedah yang telah diubahsuai ini dibandingkan dengan kaedah *Averaging*, WKF dan CSTD bagi menganalisis keberkesanan kaedah wavelet untuk penyahbunyian yang dapat mengekstrak ABRs dengan lebih cepat dan tepat. Hasil menunjukkan bahawa MCSTD mengatasi kaedah lain dengan memberikan nilai SNR tertinggi dan dapat mengesan gelombang V pada bilangan kitaran sebanyak 512 dan 1024 kitaran masing-masing untuk rangsangan chirp dan click.

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LIST OF ABBREVIATIONS

ABR	-	Auditory Brainstem Response
AEP	-	Auditory Evoked Potential
AN/AD	-	Auditory Neuropathy/dys-syndrome
APGAR	-	**A**ppearance, **P**ulse, **G**rimace, **A**ctivity, and **R**espiration.
BSAEP	-	Brain Stem Auditory Evoked Potentials
CSTD	-	Cyclic Shift Tree Denoising
DFT	-	Discrete Fourier Transform
DPOAEs	-	Distortion-product Otoacoustic Emission
DTFT	-	Discrete-Time Fourier Transform
DWT	-	Discrete Wavelet Transform
ECG	-	Electrocardiogram
ECoG	-	Electrocorticography
EEG	-	Electroencephalogram
EHDI	-	Early Hearing Detection and Intervention
EMBD	-	Extended Modified B-Distribution
EMG	-	Electromyogram
EMI	-	Electromagnetic Interference
EOAE	-	Evoked Otoacoustic Emission
EP	-	Evoked Potential

ERP	-	Event Related Potential
FMRI	-	Functional Magnetic Resonance Imaging
FFT	-	Fast Fourier Transform
FT	-	Fourier Transform
GJB2	-	Gap Junction Protein Beta-2
HI	-	Hearing Impairment
HL	-	Hearing Loss
HP	-	High-Pass
KF	-	Kalman Filter
LFP	-	Local Field Potential
LP	-	Low-Pass
MBD	-	Modified B-Distribution
MCSTD	-	Modified Cyclic Shift Tree Denoising
NHS	-	Newborn Hearing Screening
OAE	-	Otoacoustic emission
PCHI	-	Permanent Childhood Hearing Impairment
SNHL	-	Sensorineural hearing loss
SNR	-	Signal to noise ratio
STFT	-	Short-Time Fourier Transform
TF	-	Time Frequency
TOAE	-	Transient Otoacoustic Emission
UNHS	-	Universal Neonatal Hearing Screening
WHO	-	World Health Organization
WKF	-	Wavelet Kalman filter
WT	-	Wavelet Transform

LIST OF SYMBOLS

A1	-	Mastoid right
A2	-	Mastoid left
Cz	-	Vertex
Hz	-	Hertz
Fpz	-	Forehead
dB	-	Decibel
dB HL	-	Decibels Hearing Level
dB nHL	-	Decibel Above Normal Adult Hearing Level
dB SPL	-	Decibel peak equivalent sound pressure level
ms	-	milisecond
%	-	Percentage
µV	-	Microvolt
n	-	Number of samples
i	-	Wavelet decomposition level
$f(t)$	-	Measured data
$s(t)$	-	ABR signal
$n(t)$	-	Background noise
$x(t)$	-	Signal
$\psi_{a,b}(t)$	-	Wavelet function

k	-	Level
z_t	-	ABR measurement
s_t	-	Brain activity
v_t	-	Brain activity independent from the stimulation
δ	-	Threshold

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CHAPTER 1

INTRODUCTION

1.1 . Introduction

The person who has a hearing problem always face a problem in communication and lead to depression, social withdrawal and the problem with employment and access to information sources (Davis *et al.*, 2007). Hearing impairment can be categorized as slight, moderate and severe according to the National Framework for Neonatal Hearing Screening in 2013. There are three main types of hearing loss which are sensorineural, conductive and mixed (Francisco, 2013). According to WHO statistics, 1-5 in 1000 babies suffers from hearing loss (Kocur *et al.*, 2010). In Australia, 1.3 per 1000 babies having a moderate to profound bilateral permanent childhood hearing impairment (PCHI) and 0.6 per 1000 babies was unilateral PCHI which about 331 children were born with bilateral PCHI and 174 children were born with unilateral PCHI (2013).

According to Kocur *et al.* (2010), Universal Neonatal Hearing Screening (UNHS) has become one of the most important recommendations in modern pediatric audiology. It is important to perform the screening in early stage (neonatal period) as it is an action for early treatment for hearing problems. As stated by

Yoshinaga-Itano, (2003) that early detection for the newborn was very important as the first six month of age are the critical period for learning communication. Assessing the effectiveness of the screening is lied upon the evidence that hearing loss leads to decreased function and affects the quality of life while the effectiveness of the treatment can improve the function and well-being. Children with hearing impairment are more likely to experience lower self-perceived health status than those of normal children (Zaitie Satibi, 2015).

Unfortunately, this program is only successfully implemented in developing countries such as United States, Brazil, and Australia due to the high cost because in the certain country this screening was considered expensive. Other than that, this screening was conducted on the babies despite their risk status and sometimes UNHS programs simply targeted infants who presented at hospitals or well child clinics (Olusanya, 2011). According to a statement issued by medical expert Datin Dr. Siti Sabzah Hashim in the newspaper 'The Star', she mentioned that this screening only detected on high-risk babies due to their high tendency to get this disease (Loh, 2013).

In a general aspect, ABR screening often faces economic, political, and cultural challenges. Yin *et al.* (2014) state that, Malaysia also having the same problem similar to other developing countries where this screening program required the high infrastructure cost due to the instruments and manpower training costs. Other than that, Malaysia also lacks medical or laboratory staff at present, for example in West Malaysia, current doctor to patient ratio is approximately 1:800 whereas in East Malaysia, the ratio is 1:700. This ratio is lower than the recommendation ratio (1:600) set by WHO as reported by The Star in 2010, Bernama in 2011 and 2013.

In addition, very few experienced and knowledgeable personnel, medical or technical support can be made in order to do the continuous treatments and confirmation for positive newborn screening diagnosis. Public awareness is also very low and there is also the lack of interest from clinicians and hospital administrators in this program. Thus, screening is only done on the high-risk babies whereas normal babies were left out until it was too late for early intervention based on The Star newspaper article on ‘Call to screen all newborn babies’ (Loh, 2013). Thus, it is important for a policy maker to involve and support this program to improve the hearing screening system in Malaysia.

Malaysia has introduced the neonatal hearing screening program (HRNHS) to state government hospitals since 2001 as they want to minimize and prevent hearing impairment among high-risk neonates (Institute for Medical Research, 2009, Surgical and Emergency Medical Services Unit, 2009). Corona-Strauss *et al.,* in 2007 introduced a new detection paradigm using a single sweep of auditory evoked potentials resulting a fast detection for newborn hearing screening. The proposed wavelet phase synchronization stability method of Auditory Brainstem Response (ABR) single sweeps can be a new evaluation for the detection of the ultra-fast quantification of hearing loss where it is the collaboration between University of Saarland and Universiti Teknologi Malaysia (UTM).

Nowadays, there are multiple methods using for hearing testing. The evaluation of neonates and infants below the age of two to three years requires some form of electrophysiological testing in an objective manner to track the hearing problem. UNHS program also introduces two methods, as a result to overcome this problem, which is Transient Otoacoustic Emission (TOAE) and Auditory Brainstem Response (ABR). TOAE was used to determine the cochlear status in response to the tones presents to the ear while ABR is an electrophysiological response in the electroencephalography generated in the brainstem in response to acoustical stimulus (Al-Khamesy, 2002). ABR usually used for infants and was believed to be the most accurate method used to determine hearing function (Cebulla and Dieler, 2012).

Auditory Brainstem Response (ABR) is well known as the most accurate method used to determine hearing problem but this technique is difficult to be performed at the first stage of screening because of time consuming to get the signal. Noise is the foremost frustration with clinical ABR measurements. ABR needs to be recorded until 2000 to 4000 epochs from each stimulus intensity level to obtain a meaningful result. This has made the TOAE method is used in the first two-stage of screening. However, the drawback of implementing Transient Otoacoustic Emission (TOAE) method in UNHS program as it has less specificity and sensitivity compared with the ABR.

ABR accuracy is greatly affected by noise interferences from electromagnetic and myogenic sources which distort the morphology of the ABR. These problems make it very challenging to get a good respond and sometimes it is very time consuming to detect the sources of noise, especially from electromagnetic sources. It is very difficult to be identified because the noise might be evoked from equipment, circuit, and power sources where this is the disadvantage of not having a shielded room. Moreover, the recording process can cause uncomfortable to the subject because they cannot do any activities, even blinking or scratching. To overcome this problem, there are many signal processing methods have been introduced to reduce the noise. These methods are known as denoising, in which the signal is separated from the noise. In this study, there are several signal processing methods such as Kalman Filter (KF), Cyclic Shift Tree Denoising (CSTD) and Modified Cyclic Shift Tree Denoising (MCSTD) were used for denoising purpose.

1.2 . Problem Statement

Contamination in ABR signals is the most common problem occurs in ABR recording and the most challenging task to deal with. The contamination can be either come from electromagnetic and myogenic sources. These problems halt from getting a good waveform and reduce the accuracy of the signal with a higher number of artifacts. Previously, averaging technique widely used for ABR estimation, but this technique required a high number of sweeps. Besides, this technique is time consuming and in order to reduce the time of recording, the numbers of sweeps need to be reduced too. When reducing the sweeps number, an averaging technique was unable to detect the wave V. Thus, a few developing signal processing approach were implemented in this research in order to reduce the noise and also the sweeps number so that NHS can be implemented. This thesis introduced and developed a modified approach, Modified Cyclic Shift Tree (MCSTD) in order to overcome these problems.

1.3 . Objectives

The main objective of this research is to reduce screening time by implementing enhanced signal processing method. The approach is to detect the wave V with reduced number of epochs. In order to achieve this objective, several approaches are addressed in this thesis as following:

The objectives of this research are:

1. To analyze the performance of the ABR system with a fewer number of epochs.
2. To reduce the influence of noise interference.
3. To proposed a new technique, Modified Cyclic Shift Tree Denoising (MCSTD) for ABR screening.

1.4 . Scope of Work

1. Data were collected from baby, adult and hearing impairment subject.
2. Real ABR data were used to observe a minimum number of epochs sufficient to detect wave V.
3. This research only focuses on detecting wave V.
4. This research focuses on congenital hearing loss.

1.5 Importance of research

The first three years of life are the most intensive period for speech and language development. During this period, the child's brain has developed and if the hearing problem was not identified at an early period, they will face difficulty in speaking. In such case, identifying hearing loss as early as possible will enable pursuing treatment options earlier, so that can improve language, learning and social development (Zaitie Satibi, 2015). Therefore according to Siti Sabzah and Norzi (2010) hearing screening in Malaysia is very important and relevant to reduce the hearing loss problem which will give positive impact to the outcome of the existing hearing rehabilitation service as well as the cochlear implant programmed.

Applying the ABR method during first-stage screening will reduce the number of referral rates, due to high sensitivity and specificity. With the enhancement of signal processing approach such as the proposed method Modified Cyclic Shift Tree Denoising (MCSTD) should help to reduce the screening time. Furthermore, the ABR signal has no special characteristics, especially upon trials. Their components can change due to technical and physiological aspects. The electrical potential differences are the result of extracellular fields of very weak electric energy which is very complicated to be analyzed. This characteristic makes

Electroencephalography (EEG), Electrocorticography (ECoG), and Local Field Potential (LFP) signals become the most challenging in term of data processing because the temporal and spatial pattern of electric fields on the scalp and cerebral cortex are enigmatic, ephemeral, easily dismiss as noise, and usually counted as epiphenomenal. EEG recording become an ultimate challenge for most methods in signal processing due to their high complexity, low signal to noise ratio (SNR), nonlinearity and nonstationarity (Freeman and Quian Quiroga, 2013). In technical aspects, the electromagnetic or external noise can influence the quality of the ABR signal. The recording on different places can cause variation in signal quality even from the same subject. The challenge was further worsened in dealing with a very poor signal to noise ratio (SNR) while recording the ABR signal which the MCSTD method reduce noise significantly to obtain the fewer sweeps for wave V detection.

1.6 Thesis Outline

In this thesis, this research concerned on reducing the screening time and noise interference in ABR technology. This study focused on the enhancement of signal processing method in order to extract the ABR signal in a fewer number of sweeps. Therefore, the thesis is organized into five chapters. The current chapter emphasized on the problem background of ABR technology and the significance of this research in order to overcome the problem.

Chapter 2 describes the review of the current UNHS technology. It comprises the evaluation of UNHS program, the approach and comparison study on estimation the ABR signal through signal processing technique. The pros and cons of each method are referred and thus motivate the research direction to the development of the proposed method.

Chapter 3 describes the research methodology in detail. It includes the organization of equipment setup, data collection and the derivation of the proposed signal processing method. Then, the related results were discussed in chapter 4. The discussion was focused on comparing the performance of the proposed technique Modified Cyclic Shift Tree Denoising with others such as averaging, wavelet Kalman Filter and Cyclic Shift Tree Denoising. Finally, chapter 5 summarized the research finding and suggestion on further research.

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