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Implementation of wavelet packet transform and non linear analysis for emotion classification in stroke patient using brain signals

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ABSTRACT

Emotion perception in stroke patients is affected since there is abnormality in the brain. Here, researchers focused on the impact of left brain damage and right brain damage towards emotion recognition. Due to the impaired emotion recognition, it is a challenge for stroke patients to express themselves in daily communication. Hence, it is inspiring to see the possibility to predict patient's emotional state so as to prevent recurrent stroke. In this work, electroencephalograph (EEG) of 19 left brain damage patients (LBD), 19 right brain damage patients (RBD) and 19 normal control (NC) are collected as database. During data collection, six emotions (sad, disgust, fear, anger, happy and surprise) are induced by using audio visual stimuli. After normalization, EEG signals are filtered by using Butterworth 6th order band-pass filter at the cut-off frequencies of 0.5 Hz and 49 Hz. Then, wavelet packet transform (WPT) technique is implemented to localize five frequency bands: alpha (8 Hz–13 Hz), beta (13 Hz–30 Hz), gamma (30 Hz–49 Hz), alpha-to-gamma (8 Hz–49 Hz), beta-to-gamma (13 Hz–49 Hz). In WPT, four wavelet families are chosen: daubechies 4 (db4), daubechies 6 (db6), coiflet 5 (coif5) and symmlet 8 (sym8). Hurst exponents are extracted from each band and wavelet family and are classified by using K-nearest Neighbour (KNN) and Probabilistic Neural Network (PNN). Two classifications are done: comparison between three groups and comparison between six emotions. The results showed that all the H values are anti-correlated ($0 < H < 0.5$). From classification, the best frequency band is beta band, where sad emotion recorded the accuracy of 82.32% for LBD group. Meanwhile, both sad and fear emotion recorded 0.89 sensitivity score in LBD and RBD respectively. Due to its overall poor performance, RBD is found to have greater impairment in emotion recognition.

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1. Introduction

Previously, stroke is known medically as a cerebrovascular accident (CVA). It is a medical emergency where our brain is being attacked and led to complication in blood supply to our brain which causes sudden death of brain cell. These brain damages will cause slurring speech, memory loss and as well as paralysis depending on the area of damage. When the damage happened to be facial paralysis, emotion expression is almost impossible. This disability often become a challenge in daily communication with friends and family. According to the latest WHO data published in May 2014, stroke deaths in Malaysia reached 15, 497 or 12.19% of total deaths. The age adjusted death rate is 80.59 per 100, 000 of population ranks Malaysia number 97 in the world [1]. In a study, a total of 7668 stroke patients were recruited for analysis. On average, patients were aged 62.7 years (standard deviation of 12.5). Ischemic stroke accounts for 79.4% of the cohort with a slightly higher proportion of male patients (55%). Ischemic stroke incidence is estimated to increase annually by 29.5% and hemorrhagic stroke by 18.7% [2]. There are studies explaining about the emotional changes of post-stroke patients which cause psychological illnesses in certain cases [3]. Due to the region of brain damage, patients are not able to perceive either positive or negative emotions [4]. Right brain damaged patients are likely to be good at perceiving positive emotions [5]. Whereas, some stated that right brain is responsible in recognizing emotions, thus left brain damage does not cause impairment in emotion perception [6,7]. In summary, although impairment for emotion perception was more frequently observed in individuals with RBD than with LBD, there were a very fair number of studies that found no differences between the two patients group [8].

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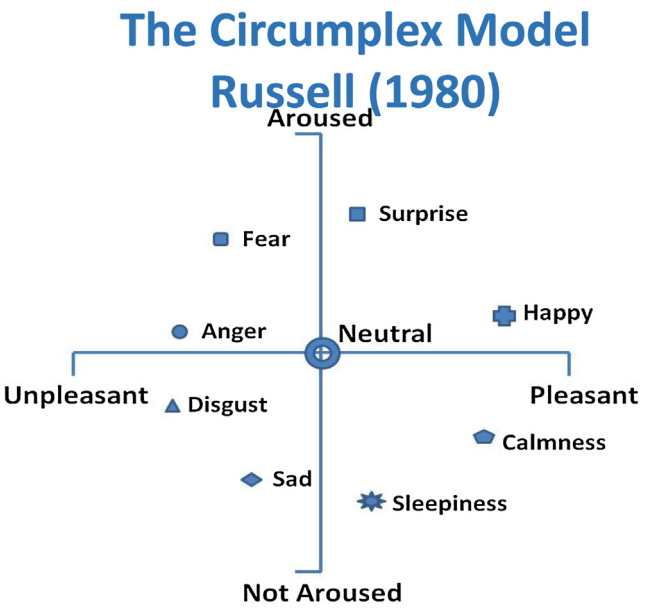

Fig. 1. Emotion model [18].

1.1. Electroencephalograph (EEG) and its importance in accessing emotion

Psycho-physiological study has been done for more than a decade now. People are interested to investigate emotions via different kind of modalities and approaches including gestures, speech, facial and physiological signals [9,10]. Electroencephalogram is a nonstationary time series biomedical signal that provides information about human brain activities. This signal has been used in emotion study since decades ago and it contributes in the area of human machine interface. There has been a lot of different modalities used in previous emotion studies including facial expression, vocal expression, human behaviour and physiological signals such as electrocardiogram, galvanic skin resistance, electromyogram, skin temperature, photoplethysmogram and electroencephalogram [11–14]. However, all methods except physiological signals are easily concealed, faked and even purposedly expressed [15]. Therefore, EEG is more reliable and could reduce masked emotions. In this paper, authors will present how EEG is used to recognize the emotional states of both stroke patients and healthy control. Physiological signals reflect the inherent emotional state changes of the subject through characteristics of physiological responses. Emotion inducement can be done by using different stimuli namely visual (pictures), audio (music), audio-visual (video clips), emotional recall paradigm, etc [17].

Emotions can be broadly categorized onto a 2D plane where there is x-axis (valence) and y-axis (arousal). From this Circumplex Model, the authors decided to choose the Big Six as the main emotions for this study (happy, surprise, sad, anger, disgust and fear) (Fig. 1).

Stroke study concerning emotions and psychological aspect has been done clinically since decades ago. Recently, people are interested in emotion investigation and the effect of brain hemisphere region in emotion perception. Different methods and database has been carried out and collected in order to test their hypotheses [8]. However, none has focused on collecting physiological data such as EEG and no machine learning techniques has been applied in investigating emotion deficits in stroke patients. Therefore, the authors will focus on presenting the proposed data collection protocol and also the preliminary signal processing process.

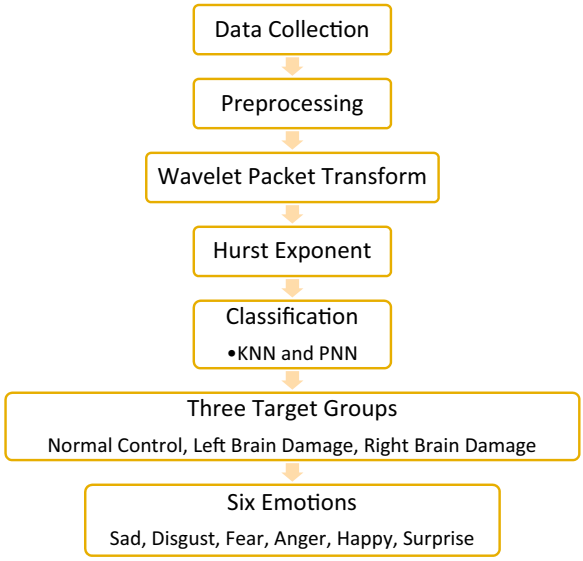

Fig. 2. Methodology Flow Chart.

In this paper, firstly, our proposed data collection protocol and signal processing will be presented precisely in methodology. Other than that, theories on the pre-processing and feature extraction method which is WPT will also be explained. Then, interpretation of our results will be shown in result and discussion section. Finally, conclusion and future work will be presented.

2. Methodology

In the beginning of this project, database is formed through data collection process. After the raw data is acquired, pre-processing and Wavelet Packet Transform is done in order to extract the Hurst Exponent. In the end, classification of six emotions and identification of groups will be done by using K-nearest neighbour (KNN). The summary of methodology flowchart is shown in Fig. 2.

2.1. Data collection protocol

2.1.1. Screening and recruiting process

EEG database in this work is collected in Hospital Canselor Tuanku Mukhris (HCTM). With the collaboration and abundant help from the clinical specialists in Neurology Department, LBD and RBD patients were diagnosed and screened. After reviewing their medical reports, short listing is done to opt out the unrelated cases. Only stroke patients with the inclusion criteria were approached in recruitment process. Meanwhile, aged-matched NC are recruited from our colleagues, patient's relatives and also HCTM staffs. Before this study is conducted, our data acquisition protocol is verified and approved by the ethical committee of HCTM and all participants or caretakers are given written consent prior to participation. Selection of subject or patients is a very strict and concise procedure in this study. Hence, inclusion and exclusion criteria are laid out in order to filter out the overlapping issues that could possibly affect our study.

2.1.1.1. Inclusion and exclusion criteria. Due to the statistics of stroke attack in Malaysia population, individuals should be between 45 and 70 years old. He or she has good eyesight or corrected-to-normal eyesight and intact hearing. In order to rule out global cognitive decline that might decrease the ability of patients to respond well in emotion study, Mini Mental State Examination (MMSE) score is used and participants that scored more than 24 (out of 30) were excluded from the study [19]. His Beck

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