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EMG Signal Recognition of Gait Pattern Using Back Propagation Neural Network for Stroke Disease Rehabilitation

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Abstract

Electromyography (EMG) is the electrical activity obtained from muscles activity. Gait pattern of leg muscles will be measured and recognized by EMG signals. The EMG signal on the leg muscles is measured by six electrodes which are filtered with 0.33Hz high pass filter (HPF) and a low pass filter (LPF) for anti aliasing. Maximum frequency of EMG is 600 Hz, that sampled perfectly by Analog to Digital Converter (ADC) using 2 KHz. Artificial Neural Networks (ANN) algorithm is applied to obtain the accuracy and optimization of EMG signal. The performance of the results are investigates based on two type of human condition, first is healthy person and second is severe person. The combination of EMG measurements with ANN has gives better results compares than without an ANN model. The results showed that the measurement for healthy individuals during normal walking conditions was 4.56 volts with a frequency of 0,00582Hz; the measurement of stroke patients which walking at normal speed is 8.80 volts and the frequency is 1,231Hz. Therefore, proposed prototype that combined using ANN algorithm has increased capability of measurement of EMG signal for normal and severe humans models.
Keywords : *EMG, ANN, Gait*

1. INTRODUCTION

As biomedical science development which is very fast. So many medical devices and medicine has been created to find a disease. One of which is EMG measuring tool, where it will display signal of muscle contraction. In general principle of medical electronics is used to determine human condition with an electronic-based equipment. This principle can be applied to the condition of neuroprosthesis, ie where the muscle strength contraction is not perfect.

At first EMG is a medical instrumentation that entirely uses analog systems and is still conventional because the system is only in a time domain. In observing it required high precision. But in reality often faced with noise emerging in signal processing. So the results obtained have a low accuracy. Therefore, the problem is it needs filters that are really accurate in reducing noise in the EMG measuring instrument.

2. BACKGROUND

This study EMG signal pattern recognition using back propagation ANN is obtain a normal gait reference. Observation on the leg muscles performance on normal gait patterns and abnormal gait patterns to find out which support muscles in walking are not working as they should be.

EMG signal processing using 3 feature extractions are Integrated EMG (IEMG), Modified Mean Frequency (MMNF), Short Time Fourier Transform (STFT). Furthermore, IEMG, MMNF,

and STFT will be input for ANN so it is expected to get more accurate data than other methods that have been used in previous research.
The observation is used as a basis reference to stimulate muscle for rehabilitate patients with stroke or post-paralysis recovery in next research.

3. LITERATURE REVIEW

Based on the research of researchers have not found the same thesis research titles, but there are other studies that are almost similar.

Rika Rokhana [1] has conducted research on the identification and classification of EMG signals on the motion of Ekstesi - elbow flexion and arm motion at a certain angle using convolution method and artificial neural network. Retrieval of EMG data using the aid of medical equipment Biopac MP30. The Biopac output is an EMG rms signal. then digitally filtered by Band Pass Filter with cut off frequency 50Hz and 500Hz. thereafter, an EMG signal convolution process is performed on the FIR filter impulse response. The signal identification is done by artificial neural network method.

Moreover, Angkoon [2] has proposed a method that eliminate white Gaussian noise on hand-generated EMG signals. The objectives of this study were to present a novel feature that tolerate with white Gaussian noise. Results showed that a modified mean frequency (MMNF) is the best feature comparing with others in the quality of the robustness of EMG features with WGN point of view. It is shown that MMNF can be used as feature in augmenting the other features for a more powerful robust feature vector. Future work is recommended to combine the new multi-feature sets with MMNF.

On the other hand, Eldin [3] did recognition of EMG signal patterns on hand gestures using the Artificial Neural Network method and the wavelet method. The proposed work aimed at extraction of different hand gestures based from EMG signals. The various features extracted were classified using ANN. The ANN classified the signals successfully from the gestures and the efficiency of the classification can be increased if more number of signals are taken. The designed ANN has successfully classified the gestures with minimum computational time. The classified EMG signals can be used to develop the human computer interface which help the disabled people to interact with computer devices.

4. SYSTEM MODEL

This study observe normal gait pattern during walking that involves the thigh muscles and calf muscles. The muscles activity is observed through by capturing bio potential by six electrodes which shown in Fig. 1. Two part of the muscle are observed using a pair of EMG electrode, such as interceptor which is placed on the outer thigh, whereas a reference electrode is placed on the inner thigh. Another pair of electrodes that serve as inserts for the second EMG intercepting block are placed on the outside of the calf, a reference placed on the inside of the calf.

The signal from each electrode would be filtered between 0.33Hz and 600Hz. In order to fufill Nyquist rate, ADC sampling frequency is set to 2 KHz. A simulatneously data is taken from each part of the blocks. Due to frequency power is 50 Hz, then could be ignored which able interferer the EMG signals.

Because the frequency of the power grid is 50Hz, then the frequency should be discarded because it definitely interferes with the EMG signal. There are three types of extarction of the signal information, such as :

a. Integrated EMG (IEMG)

$$IEMG = \sum_{i=1}^{N} |x_i|. \qquad (1)$$

This feature extraction based on time domain. It shows when muscle contraction occurs. In this case, the information that can be obtained is the periodic pattern of contraction.

b. Modified Mean Frequency (MMNF)

$$MMNF = \frac{\sum_{j=1}^{M} f_j A_i}{\sum_{j=1}^{M} A_j} \qquad (2)$$

This feature extraction based on frequency domain. It is used to get the average frequency that occurs during the walking process.

c. Short Time Fourier Transform (STFT)

$$STFT_x(t,\omega) = \int W^*(\tau - t)x(\tau)e^{-j\omega\tau}d\tau \qquad (3)$$

This feature extraction is to obtain the frequency spectrum at a certain time limit.
In this work, five people who are in normal condition (35-50 years old) perform tests for three activities, such as walking at low speed, walking at normal speed, and walking quickly. Therefore 15 value combinations have inventory for inputs on ANN. Moreover, five people suffering from stroke aged 45-60 years) perform tests only for two activities, such as walking at low speed and walking at normal speed. Therefore 10 value combinations have inventory for input on ANN. So there are 25 total combinations for all conditions that are important for ANN input.

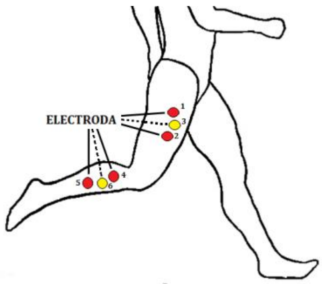

Figure 1. Position of Electrode Laying

5. DEVELOPMENT AND PROTOTYPE EMG

Shown in figure 2, IC AD8266 is used to provide bio-potential gain of a pair of electrodes. Furthermore, HPF is used to remove DC signals while LPF is used for anti-aliasing filter. VR1 is used to adjust the output voltage to match the working voltage of the ADC. 10 bit data series is converted from EMG signal during ADC process.

Data series of the signal is processed with digital filter with spectrum as shown in figure 3. It ensures that the data series frequency between 0.33Hz and 600Hz, and a notch filters at 50Hz frequency. All digital filters using 2nd order. Feature extraction IEMG, MMNF, and STFT are implemented to filtered data series.

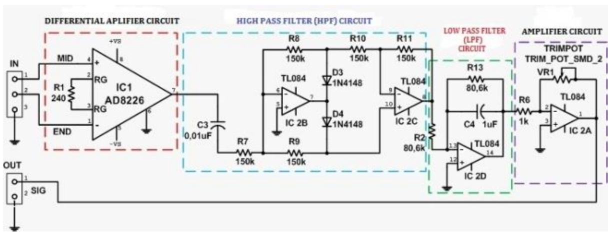

Figure 2. Signal Conditioner

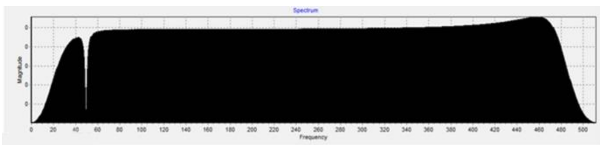

Figure 3. Digital filter spectrum

For accuracy of EMG measurements, methods that can work smart and provide optimal value are needed. Measurement of feature extraction will be used as ANN input. In the learning process, the conditioned EMG signal extraction feature is the target. In addition, more prioritize the achievement of MSE (Mean Square Error) than on the number of iterations.

6. RESULT AND DISCUSSION

Data retrieval is done on the sample in walking state. Figure 4 shows that walking operation a normal person who walks at slow speed. One wave is one cycle of walking. The magnitude shows the bio potential of muscle during contractions. The yellow line shows that the thigh EMG and the green line is calf EMG. The thigh muscle has produce greater bio potential than calf muscle. It suggests that to walk, the thigh muscle produces a harder contraction than the calf muscles. In figure 5 shows that the STFT of the thigh muscles and in figure 6 shows the STFT of then calf muscles.

Figure 10 shows one of the samples is normal person who walks at quick. The fundamental difference with Figure 7 is magnitude (peak to peak voltage) and frequency. It means that the person whose EMG is shown in figure 10 walk faster and the bio potential is greater than the person whose EMG is shown in figure 7. But when compared with the figure 4 the frequency should be less than frequency in figure 7; it is caused by leg length. In this study did not include this parameter. The STFT of the thigh EMG and the calf EMG of figure 7 is shown in figure 8 and figure 9. And the STFT of the thigh EMG and the calf EMG of figure 10 is shown in figure 11 and figure 12.

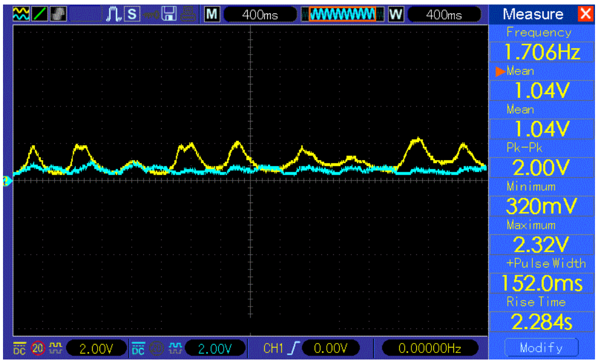

Figure 4. A sample of normal person walks at slow speed. The yellow shows the activity of the thigh EMG, and the green indicates activity of the calf EMG in oscilloscope.

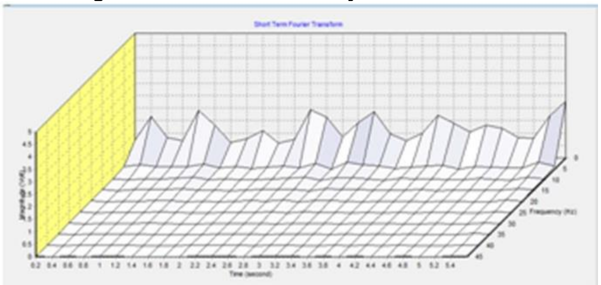

Figure 5. STFT of thigh EMG of a normal person walks at slow speed sample.

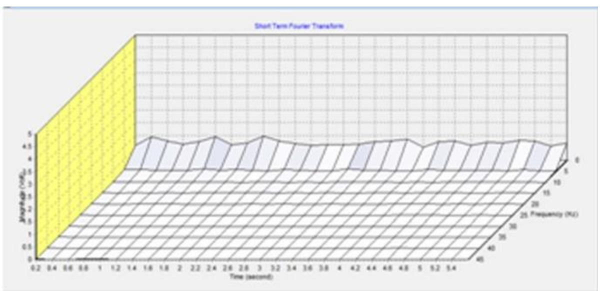

Figure 6. STFT of calf EMG of a normal person walks at slow speed sample.

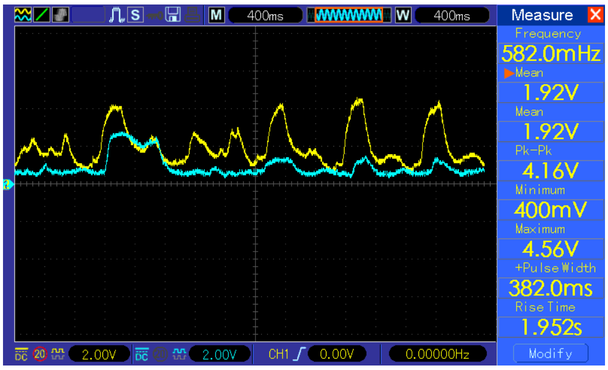

Figure 7. A sample of normal person walks at normal speed. The yellow shows the activity of the thigh EMG, and the green indicates activity of the calf EMG in oscilloscope.

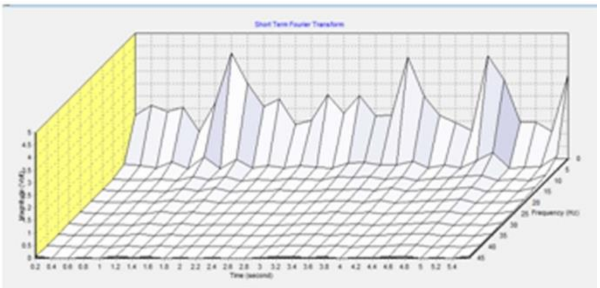

Figure 8. STFT of thigh EMG of a normal person walks at normal speed sample.

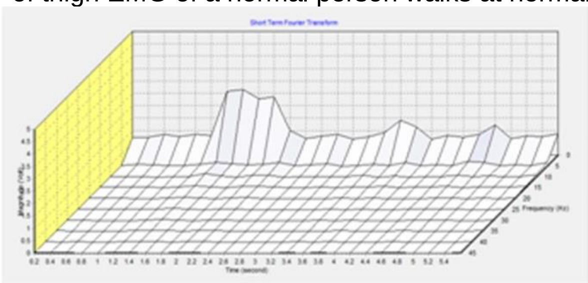

Figure 9. STFT of calf EMG of a normal person walks at normal speed.

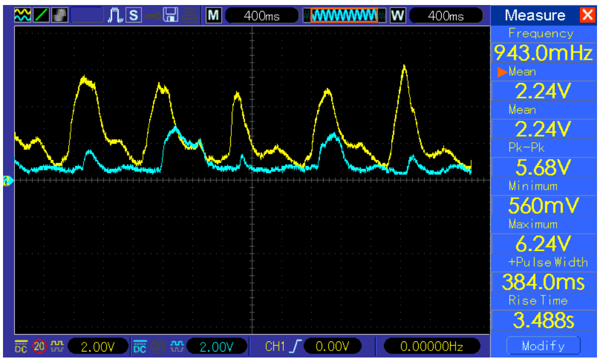

Figure 10. A sample of normal person walks at quick. The yellow shows the activity of the thigh EMG, and the green indicates activity of the calf EMG in oscilloscope.

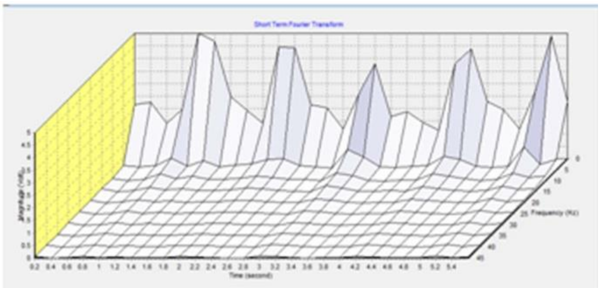

Figure 11. STFT of thigh EMG of a normal person walks at quick sample.

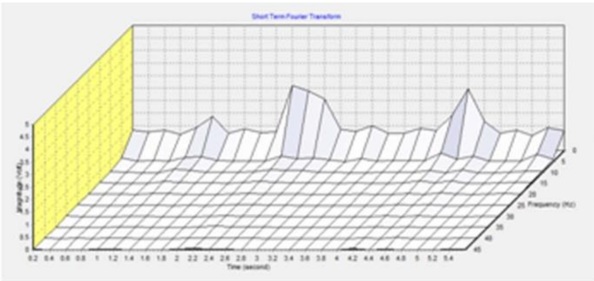

Figure 12. STFT of calf EMG of a normal person walks at quick sample.

In figure 13 shows a stroke patient who walk at slow speed. It is very different pattern with person who walks normal. It is indicated muscle tension. Between the thigh muscles and calf muscles do not experience periodically simultaneously. It is also shown in figure 16. Stroke patient who walk at normal speed have greater frequency and magnitude than stroke patient who walk at slow speed. It means to walk at quick requires more energy that is described in the form of magnitude and frequency. The STFT of the thigh EMG and the calf EMG of figure 13 is shown in figure 14 and figure 15. And the STFT of the thigh EMG and the calf EMG of figure 16 is shown in figure 17 and figure 18.

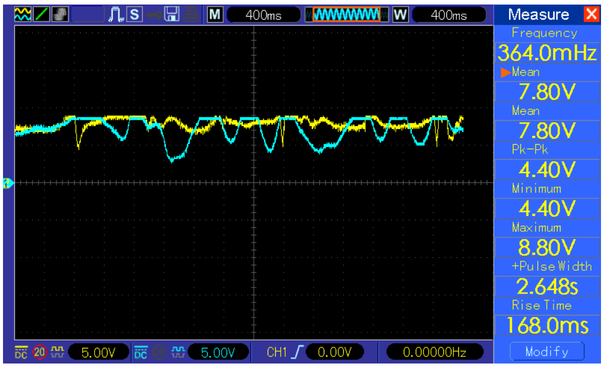

Figure 13. A sample of stroke patient walks at slow speed. The yellow shows the activity of the thigh EMG, and the green indicates activity of the calf EMG in oscilloscope.

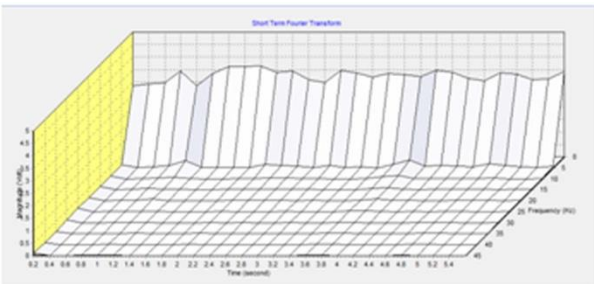

Figure 14. STFT of thigh EMG of a stroke patient walks at slow speed sample.

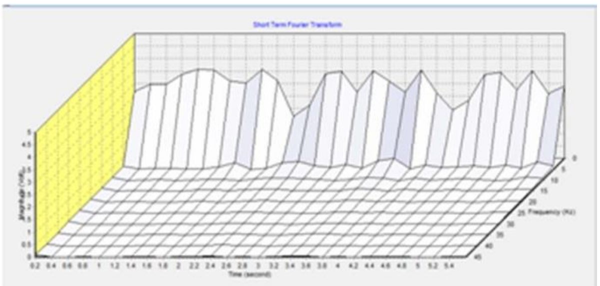

Figure 15. STFT of calf EMG of a stroke patient walks at slow speed sample.

Figure 16. A sample of stroke patient walks at normal speed. The yellow shows the activity of the thigh EMG, and the green indicates activity of the calf EMG in oscilloscope.

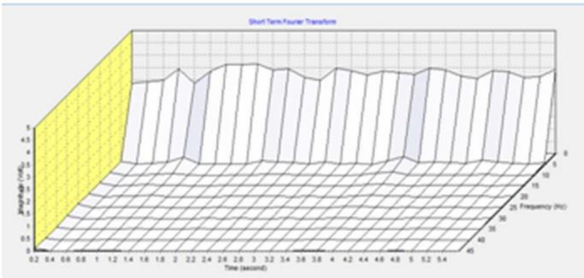

Figure 17. STFT of thigh EMG of a stroke patient walks at normal speed sample.

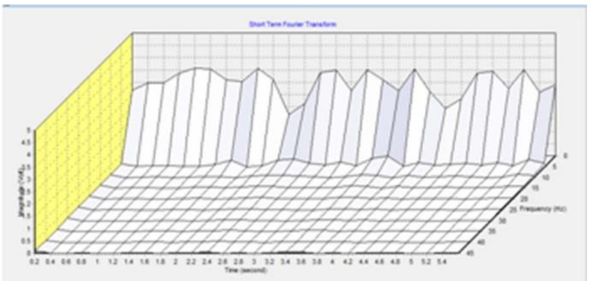

Figure 18. STFT of calf EMG of a stroke patient walks at normal speed sample.

Figure 18 shows that ANN has several parameters to be determined before learning. In this study Epoch is set at 10000 iterations, learning rate is set at 0.1, alpha is set at 0.5, and minimum MSE is set at 10^{-7}. All characteristic extraction data from all samples was learned using ANN with target code of movement. In figure 19 shows MSE chart, it is achieved in the iteration to 1200.

From these results, there are differences in signal patterns that are very striking on the pulse width. The analysis results obtained the average pulse width on the normal person signal pattern equal to ≤0.4 seconds, while in stroke patients equal to ≥0.7 seconds.

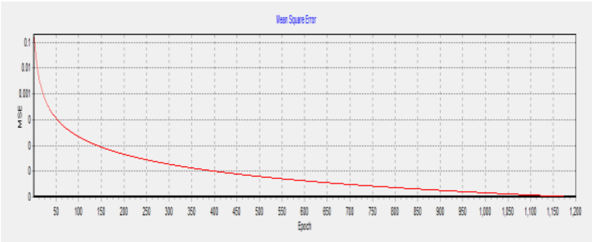

Figure 18. MSE of ANN

7. CONCLUSION

EMG signal activity contained in the thigh muscles and calf muscles have uniqueness in each foot movement, recognition of EMG signal pattern can be used to determine the condition of normal and abnormal feet. The pattern of EMG signals in normal people when walking slowly, moderately and quickly is seen more regularly than the EMG signal pattern in people with strokes whose pattern is very irregular.

Based on EMG signal pattern recognition in normal persons and stroke patients, the average pulse width on normal person signal pattern is ≤ 0.4 seconds, whereas in stroke patients ≥ 0.7 seconds. ANN can be used to distinguish patterns of EMG signals in normal people and strokes more accurately and optimally.

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