

I. INTRODUCTION

The recognition of handedness is most often done by observing the hand used for writing. This may not be exactly the true handedness of the person as left handers may be forced to write using right hand since childhood and gained a common practice to write using right hand. Besides, environment also plays an important role to alter the natural handedness of a person due to the majority ergonomics of equipment aimed for the right hander for example computer mouse, guitar, golf club, so on and so forth.

In scientific investigation, the assessments and analyses of handedness are conducted using the Edinburgh inventory which include answering several handedness questions on how a person performs daily activities such as writing, throwing, spoon handling and so on to a total of 10 questions and from these habits, handedness is then determined [1]. Although the feasibility of this method is high, it may not be exactly true when a lefty is forced to cope with the right hander dominant world that they had changed the way they use things naturally or maybe been taught to use right hand for various activity since childhood. Another downside of this method is that it needs the subjects to be fully awake and in normal psychological condition so that they can answer those projected questions to its true extent. Therefore, an alternative handedness detection system is introduced in this research in hope for better and more accurate handedness determination.

The aim and objective of this research is to determine the handedness of a person using data obtained from Electroencephalogram (EEG). The occipital region gave a higher inter-hemisphere coherence for left hander than right hander [2]. From this discovery, experiment was setup in this research to determine the mean EEG coherence of subjects which is the average connectivity or linkage between the left brain occipital region and the right brain occipital region. The importance of discovering handedness is especially significant for infants. All of us are born with a specific handedness. Some lefties are forced to use right hand to handle writing or the usage of computer mouse and this caused them to bury their full potential as a left handed person who excels in many fields in the community. The lefties, if given appropriate cultivation can achieve performance greater than the right handed counterpart. Therefore, if the handedness can be detected at infant stage, parents can be ready to have a gifted special child and prepare some

One of the advantages of using the Edinburgh Inventory is that it is immediate. A particular subject only needs around three minutes to complete the inventory and find out his or her handedness. It is also easy to perform as one can check the result oneself at home after obtaining the inventory form. However, the inventory is not applicable for patients who are unconscious or for toddlers who are not mature enough to perform the evaluation. In this context, patients who are not psychologically normal, or are not fully awake or are under the influence of alcohol or other chemicals also may not find the results appropriate.

Aside from Edinburgh's and Annett's discoveries, there are actually many more inventories or questionnaires created. The Dutch scientists had created a new questionnaire [6, 7], after cited the difference of items or actions used to determine handedness [8, 9]. The research was conducted in search for the highest factor loading items or strongest determinant for the handedness inventory. Comparisons of different items used for different inventories or questionnaires were depicted from the research and edited in the Table 2 below:

Table 2: The Comparison of Different Inventories or Questionnaires

Item	Crovitch and Zener (1962)	Annett (1967)	Oldfield (1971)	Raczkowski, Kalat and Nebes (1974)	Van Strien (2002)	Dragovic (2004)
Writing	☆	☆	☆	☆		☆
Throwing	☆	☆	☆	☆	☆	☆
Holding toothbrush	☆	☆	☆	☆	☆	☆
Using scissors	☆	☆	☆	☆		☆
Drawing	☆		☆	☆	☆	
Holding racquet	☆	☆		☆	☆	
Striking a match		☆	☆	☆	☆	☆

The stars in the table above mark the exiting elements or items in each inventory or questionnaire. Based on the table, it is noticed that the actions throwing and holding toothbrush, both involved in all of the investigated handedness determination methods. The investigation tells

activities. The participants were then asked to watch either animation or graphical stimulations for five minutes. The EEG signals taken were then analyzed for their accuracy, having known the handedness of each participant.

The second experiment was carried out to test the accuracy of the handedness detection system created and also to further develop new analysis towards the discovered feature of the left-handed subjects. The experiment was took place in conjunction with a weekly Tai Chi practice for three months in an effort to promote the healthy exercise of Tai Chi and encourage people from all range of ages to take part. In this event, the participation was free of charge, free food and drinks were provided and medical check-up was also offered as to monitor the participants' health improvement.

A simple booth was set up to attract volunteers to participate in the experiment. Only left-handed subjects were asked to participate. Sixteen volunteers mostly females, aged from as young as seven years old to as elderly as seventy years old, claimed to be left-handed took part in this experiment.

In this experiment, the subject was set to watch an animated video in High Definition (HD) named Partly Cloudy [10]. There are several reasons the animation was chosen as the experiment control. First, having subjects to view animation is better than a stream of photos or pictures because animation can draw subject's attention better. With a proper story line, subjects will be eager to view the animation until the end with high concentration. Next, it is better than cartoons as this animation is in 3D and will provide more graphical stimulations than a cartoon, which is colored pictures displayed in a fast rate. The highly detailed animation, when played in HD will provide maximum stimulation to the subjects. Besides, showing animation is better than playing a non-graphical video like a short movie clip or trailer of a film is that movie usually involves talking and chatting. This will cause the subject's focus switched to hearing instead of watching. A movie usually contains sudden actions and moments of silence where there is not much happening. The sudden actions will cause spikes in the EEG signal due to sudden increase in amplitude while the scene switching, slow momentum part of the movie will cause stagnant or low EEG signal frequency. The animation Partly Cloudy [10] was chosen because throughout the length of the animation, it will incur curiosity from the subject, keeping their EEG signal band to stay between Alpha and Beta, avoiding Theta and Delta. The 5 minutes length of the animation, together with the sample rate of 256 Hz, will give enough time samples for analysis. Finally the

4.1 Analysis on EEG Signal Decomposition with Wavelet Transform

The following two figures, Figures 2, show the original EEG data of O1 and how they are processed to obtain the four EEG waves. The subject is a known left handed male adult and he was instructed to sit still and watch some animations from the computer during the acquisition of EEG data. The original EEG data, which was sampled at a rate of 256 Hz for 3 to 5 minutes, yield a total of 46080 to 76800 time sample length, calculated by multiplying 256 with 3 or 5 and then with 60 seconds. However, not all samples were useful especially the front and rear end of the data where the recorder was not recording the EEG signals from the subject as the recorder was being connected and disconnected from the electrode from the subject. Moreover, a smaller sample size was used to perform the processing so that the process is faster and the chance of it prone to error sample is lower. The following data samples are all limit to samples ranged from 10501 to 12000 of the original time sample unless stated otherwise, yielding a total of 1500 time samples. The 1500 samples for O1 are shown in Figures 2. After that, the 1500 samples undergone wavelet transform and the approximate coefficients of different wavelet decomposition level were shown at the left column while the detailed coefficient of different wavelet decomposition level were shown at the right column. The first row of approximate coefficient and detailed coefficient were the signals after undergone the first level of wavelet decomposition while the second row of approximate coefficient and detailed coefficient were the signals after undergo the second level of wavelet decomposition and so on until the fifth row. From there, the corresponding EEG waves Beta, Alpha, Theta and Delta were determined. It is easily noted that the similarities of the Alpha bands, Beta bands, Theta bands and Delta bands are of high similarities. In this research, the range of Gamma wave activities is omitted because Gamma range is more known to high level brain functionality including cross communication between different parts of the brain. In the Figures 2, Alpha waves are at the fifth shorter wave on the right; Beta waves are at the third shorter wave on the right; Theta waves are at the fifth or last shorter wave on the right; Delta waves are at the fifth or last shorter wave on the left.

Based on Figure 2, it can be seen that the length of the wave for the approximate coefficient A1, which is the first shorter wave on the left, after the first level of decomposition is only half of the original EEG signal. This is due to the principle of wavelet decomposition. In wavelet decomposition, the signal of 1500 samples original EEG data gone through a low pass filter and a high pass filter simultaneously. The signal that was treated with low pass filter was

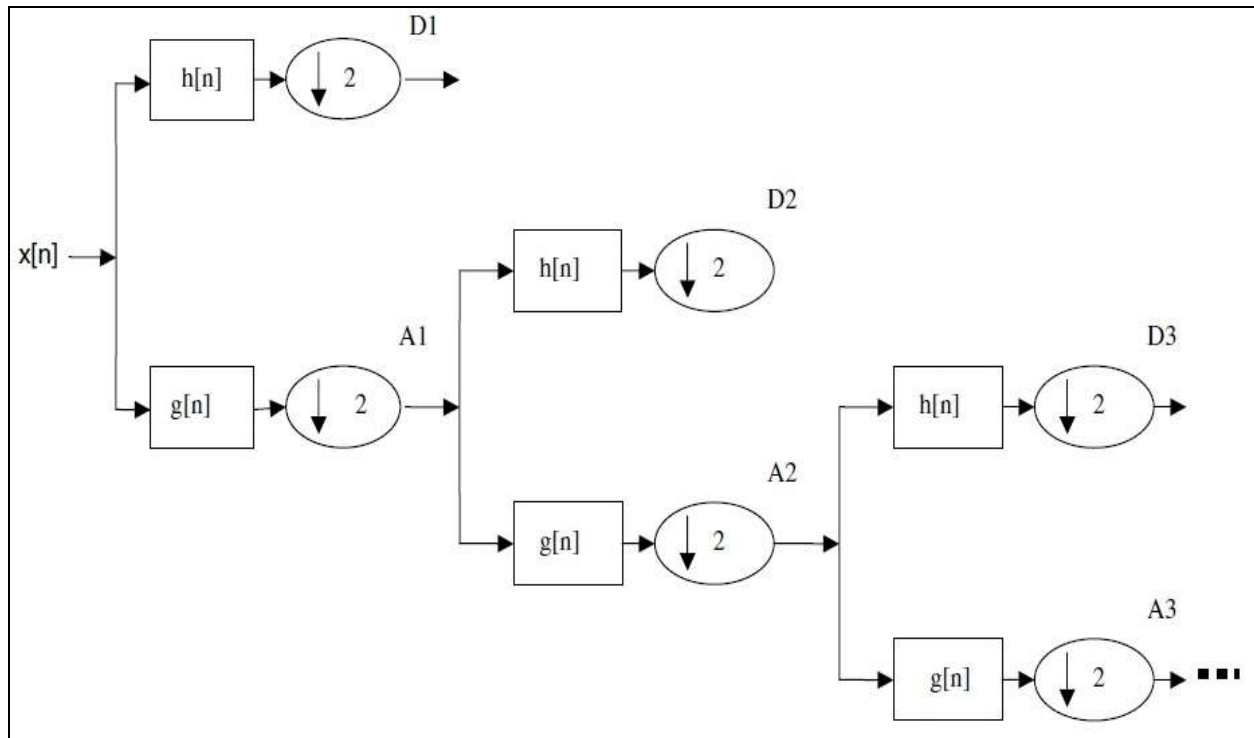


Figure 3: The Procedure of Wavelet Decomposition.

4.2 Analysis on the Mean EEG Coherence

Based on Figure 2, it can be seen that the original EEG data is more or less identical. Moreover, the four types of waves found from that two figures also looked very alike. It is observable that the coherence between these waves and also the mean EEG coherence of the O1 channel yielded a high score. The likeness of the signals, both original and processed, of a left-handed subject shown in Figure 2 can be seen more vividly if it is compared to the signals from a right-handed subject. After the four types of waves were identified, the mean EEG coherence was obtained by calculating the average of the coherences of each types of waves as shown in Figure 4.

Again, it is very clear that the left-handed subject has higher coherences for all types of waves than those of the right-handed subject. The effect of coherence can be seen more clearly when the shape or value of the coherences of Theta and Delta signal is almost identical to one another. The mean EEG coherence calculated for both of the left handed and right handed subjects as shown in the table below.

Until this stage, the algorithm is understood and the handedness system is ready to go for a run. As a start, the mean EEG coherence midpoint value to distinguish between left handed subjects and right handed subjects is set to 0.50. Below shows result of the determination of handedness using the system developed.

Table 5: Mean EEG Coherence for a Left Handed Subject and a Right Handed Subject

Subject Handedness	Subject Code	Mean EEG Coherence	Determined Handedness
Left	L1	0.721115	Left
	L2	0.625675	Left
	L3	0.492867	Right
	L4	0.667909	Left
Right	R1	0.219505	Right
	R2	0.149226	Right
	R3	0.358420	Right
	R4	0.426661	Right

Based on Table 5, it can be seen that all of the determination yield the correct handedness except subject L3. The 1500 samples used in the calculation of handedness for the target L3 is from 26501 to 28000 instead of the usual 10501 to 12000 because it was noticed that L3 had switched the activity he was doing from playing games to watching animated cartoon around one minute after the experiment was conducted. However, after choosing the best signal to be processed, it also yields a result showing his handedness wrong.

4.3 Analysis on the Diagnostic Accuracy

Diagnostic accuracy is an expression of how well the test results corresponded with the presence or absence of the target condition[16]. Diagnostic accuracy of this handedness determination system can be carried out using the data below[17, 18].

Table 6: Mean EEG Coherence for a Left Handed Subject and a Right Handed Subject.

Outcome of Determination	Real Handedness		
	Left	Right	Row Total
Left	$TL = 3$	$FL = 0$	$TL + FL = 3$
Right	$FR = 1$	$TR = 4$	$FR + TR = 5$
Column Total	$TL + FR = 4$	$FL + TR = 4$	$N = TL + TR + FL + FR = 8$

	R2	0.149226	Right
	R3	0.358420	Right
	R4	0.426661	Right

The detection of handedness of the subject L3 is now changed from right to left. This change leads to the need of calculating the new accuracy. Table 8 shows a new result for calculating accuracy based on the new midpoint with the highlighted objects which are affected by the new midpoint.

Table 8: Mean EEG Coherence for a Left Handed Subject and a Right Handed Subject with Adjusted Midpoint.

Outcome of Determination	Real Handedness		
	Left	Right	Row Total
Left	$TL = 4$	$FL = 0$	$TL + FL = 4$
Right	$FR = 0$	$TR = 4$	$FR + TR = 4$
Column Total	$TL + FR = 4$	$FL + TR = 4$	$N = TL + TR + FL + FR = 8$

The result of the calculation above shows that the accuracy of this handedness determination system is 1 or 100%. This is the ideal situation which depends heavily on the segment of data chosen to be analyzed as understood in the adjustment of 10501 to 26501 for L3. Also it is needed to understand that the mean could have been different if more data are entered upon calculation.

V. CONCLUSIONS

The testing module is developed to detect the handedness of a subject using EEG which is fast in performance and easy to use. The system is free from habitual constraint which is the downside of the current inventories. It is recommended to be use on patients who are unconscious or unable to answer questionnaire. Some does to little kids as to determine their handedness before their development of many habitual handedness distinctive tasks. However, as EEG signals are required for the detection, rather than just a softcopy of attachment that can be sent throughout the internet, hence this system are deemed more suitable for clinical use rather than domestic procurement [15-19]. Following this up, as subject need to actually being sampled by

the EEG equipment individually, it is actually time-consuming and of extreme difficulty to collect large number of EEG data at a same time, which in contrast can be easily done by inventories or questionnaires. In this system also, due to a single midpoint to distinguish between left hander and right hander, it is therefore unable to class subjects to ambidextrous group which can use both hands to perform various tasks including writing. Based on the finding from experiment two, the accuracy of the handedness detection system is more than 50%. This score is quite satisfactory as we are not known of the participants' real natural handedness. Besides, the various disturbances and noises during the recording of EEG signal make it both challenging.

REFERENCES

- [1] Oldfield, R.C., 1971. The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, 9(1), pp.97–113.
- [2] Nielsen, T. et al., 1990. Interhemispheric EEG Coherence during Sleep and Wakefulness in Left- and Right-Handed Subjects. *Brain and Cognition*, 14, pp.113–125.
- [3] Dragovic, M., 2004. Towards an improved measure of the Edinburgh Handedness Inventory: A one-factor congeneric measurement model using confirmatory factor analysis. *Laterality*, 9, 411-419.
- [4] Leong WY, Mandic DP 2007, *Noisy component extraction (noise)*, IEEE International Symposium on Circuits and Systems, IEEE, Pages:3243-3246, ISSN:0271-4302
- [5] Williams, S.M., 1991. Handedness inventories: Edinburgh versus Annett. *Neuropsychology*, 5(1), pp.43–48.
- [6] Van Strien, J.W., 1988. *Handedness and hemispheric laterality. Thesis, Vrije Universiteit Amsterdam, the Netherlands.*
- [7] Crovitz, H.F., and Zener, K., 1962. A Group-test for Assessing Hand- and Eye-Dominance. *American Journal of Psychology*, 75, 271-276.
- [8] Raczkowski, D. et al., 1974. Reliability and Validity of some Handedness Questionnaire Items. *Neuropsychologia*, 12, 43-47.
- [9] *Partly Cloudy*. 2009. [Video] Directed by Peter Sohn. USA: Pixar Animated Studio.
- [10] Übeyli, E.D., 2008. Wavelet/mixture of experts network structure for EEG signals classification. *Expert Systems with Applications*, 34(3), pp.1954–1962.
- [11] Bossuyt, P.M. et al., 2003. The STARD statement for reporting studies of diagnostic accuracy: explanation and elaboration. *Annals of internal medicine*, 138(1), pp.W1–12.
- [12] Zhu, W., Zeng, N. and Wang, N., 2010. NESUG 2010 Health Care and Life Sciences Sensitivity , Specificity , Accuracy , Associated Confidence Interval and ROC Analysis with Practical SAS ® Implementations K & L consulting services , Inc , Fort Washington , PA Octagon Research Solutions , Wayne . , pp.1–9.
- [13] Tung, R. and Leong, W.Y, 2013, *Processing obstructive sleep apnea syndrome (OSAS) data*. Journal of Biomedical Science and Engineering, 6, 152-164. doi: 10.4236/jbise.2013.62019.

- [14] Leong W.Y., Mandic D.P., Liu W., 2007, *Blind Extraction of Noisy Events Using Nonlinear Predictor*, ICASSP 2007, IEEE, Pages:657-670, 1520-6149.
- [15] Leong W.Y., Homer J., 2004, *Implementing ICA in blind multiuser detection*, IEEE International Symposium on Communications and Information Technology (ISCIT) 2004., Vol.2, pp.947-952.
- [16] Leong WY, Mandic DP, M Golz, D Sommer, 2007, *Blind extraction of microsleep events*, 15th International Conference on Digital Signal Processing, pp.207-210.
- [17] Leong YW, 2006, *Implementing Blind Source Separation in Signal Processing and Telecommunications*, PhD Thesis, The University of Queensland.
- [18] B. Ginzburg, L. Frumkis, B.Z. Kaplan, A. Sheinker, and N. Salomonski, 2008, Investigation Of Advanced Data Processing Technique In Magnetic Anomaly Detection Systems, *International Journal On Smart Sensing and Intelligent Systems*, Inaugural Issue VOL. 1, NO. 1, MARCH 2008, Pages: 110-122.
- [19] Xu Xiaobin, Zhou Zhe, Wen Chenglin, Data Fusion Algorithm of Fault Diagnosis Considering Sensor Measurement Uncertainty, *International Journal On Smart Sensing and Intelligent Systems*, VOL. 6, NO. 1, FEB 2013, Pages: 171 – 190.
- [20] E. B. Tan, D. and Leong, W. (2012) Sleep disorder detection and identification. *Journal of Biomedical Science and Engineering*, 5, 330-340. doi: 10.4236/jbise.2012.56043.