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LEFT-HANDEDNESS DETECTION

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Abstract - In this paper, a new left-handedness sensing and detection module, has been developed to classify the handedness of a person. Handedness of the person can be determined from the EEG data captured and further confirmed using a simple game as testing module. EEG signals were obtained from three locations namely A1, O1 and O2. The signals were then classified into four different frequency bands: Alpha, Beta, Delta and Theta before they were used to determine the Mean EEG Coherence. Generally the left handed person has higher Mean EEG Coherence which means that there are more connections between the left and right hemisphere of cerebrums through the corpus callosum. Based on research, personal non-right handedness has been associated with both increased corpus callosum size and increased functional interaction between cerebral hemispheres. To relate the former to the later, it is suggested that the increased size of corpus callosum, which somehow passes information between the two sides of the brain, allows greater inter-hemispheric communication. Handedness is determined based on this criterion. At the end of the research, the module developed enables the determination of handedness personnel.

Keywords: left-handedness, Electroencephalogram (EEG), detection, coherence, decomposition

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 equipment with left handed ergonomics. Besides, it may also work on unconscious or paralyzed patients for use in neuropsychological and other clinical experimental works.

II. EARLY HANDEDNESS DETECTION METHOD

It was about 40 years ago since the first creation of a method to determine the handedness of a person. An inventory of 10 items with a set of instructions and subjects is needed to choose its handedness when performing various activities including unilateral activities such as writing and drawing and the results are obtained from about 1100 individual [3,6-7]. In that research, the developed inventory is said that it is less time consuming compared to methods that require observing of subjects performing various tasks. However, this inventory depends on the probable inaccuracy of subjects when they will be questioned on activities they seldom perform or on some activities that is so habitual that they take minor consideration on true natural handedness preference. Here are the steps using an Edinburgh inventory. First, one or two checks or ticks were given to each task or activity. One check on either left or right hand indicates the preference of that particular hand in performing that one task. Two checks on either left or right hand column indicate that that person would not have used the other hand for that activity, meaning a strong preference for that activity. A tick for both left and right hand column tells that the task can be carried out using both hands. The total checks are summed out for both hands that is *LH* for left hand and *RH* for right hand. A cumulative total *CT* is obtained from summing both the checks of both hands. The difference *D* is calculated by subtracting *LH* from *RH*. The final result *R* is as in the following:

$$R = (D/CT) \times 100 \tag{1}$$

where R = Result, D = Difference, $RH - LH$ and CT = Cumulative total, $RH + LH$

After the acquisition of the result, an interpretation of the calculated result can be carried out to determine the handedness of a person by referring to the following Table 1.

Table 1: The Result Interpretation for the Edinburgh Inventory

Result Value, *R*	Handedness
Less than negative 40	Left handed
Between negative 40 and positive 40	Ambidextrous
More than positive 40	Right handed

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 us that these two actions are the most common but not the best [6], because the best item to determine handedness is the hammering action which needs pinpoint accuracy and also exact timing and modulation of force. Writing is unexpectedly not involved in all inventories maybe because of possible dysgraphia from targeted subjects and thus drawing is a best substitute to writing. Out of the six inventories, only the one suggested by Crovitch and Zener offers the reversed items. The five included items or actions are targeted for the opposite handedness of a person as we can understand that all five actions listed require static and steady act while the dominant hand is performing detailed or dynamic actions.

III. HANDEDNESS DETECTION SYSTEM

Electroencephalogram is commonly acquired from a patient or even normal subjects to find out the electrical signal generated by their brain [4-5, 20]. The basis of this research is originated from the findings of a research [2], which Nielsen found out that the mean EEG coherences for left handers are higher than those of right handedness subjects at the occipital region. Therefore, a simple experiment was set up, along with a set of algorithms to determine the handedness of an individual. First, we need to obtain EEG signals from a subject. By using the following EEG equipment set:

Table 3: The List of Equipment Set

Equipment	Details
2-channel recorder	After configuring it from the computer and the dock, it can record EEG signals obtained from the electrodes.
Interface Dock with USB wire	The dock not only provides the USB communication between the recorders to a computer, it also charges the electrical power needed by the recorder.
Gold electrodes taped to a head band	Sensitive electrodes to capture electrical signal or EEG signal from the brain.

Experimental Setup

The first experiment was carried out to test and tweak the program primarily and also to distinguish the feature of EEG signals from left-handers and right-handers. Eight university under-graduates were invited to participate in this experiment with four being left-handed and four being right-handed. The handedness of participants was confirmed through some daily life 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 genre and theme of the animation also selected with upmost care because the experiment was meant for subjects of both sexes with age ranged from 7 to 70 years old. The animation Partly Cloudy is rated G for general audience with the genre of comedy, family and fantasy with a theme of friendship. The preview of the animation can be seen at the following screenshots in Figure 1.

Figure 1: Screenshots from the animation Partly Cloudy [10]

The handedness of the participants were unable to be confirmed verbally and the EEG signals of the volunteers were both tested by the system and shown to them as a check of handedness to see whether the results were of satisfaction. Some of them were as excited as I was during the experiment as they themselves wondered what are their handedness. During the preparation of the recorder, which includes deleting previous data from the recorder, history of their usage of hand was asked. There were some elderly subjects claimed that they were natural left-handed during childhood. This group of elder subjects was forced to perform tasks especially writing and eating with right hand by their parents. Physical punishments were applied whenever left hand was used for these dominant tasks. One 40 years old subject continues this tradition and forces her daughter to use right hand-writing as well. She claimed that handwriting is better when using right hand especially writing Chinese characters. Finally, the data were also kept for further research and analysis.

IV. RESULTS AND DISCUSSIONS

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 the approximate coefficient A1 while the signal that was treated with high pass filter was the detailed coefficient D1 as shown in Figure 3 [11, 12].

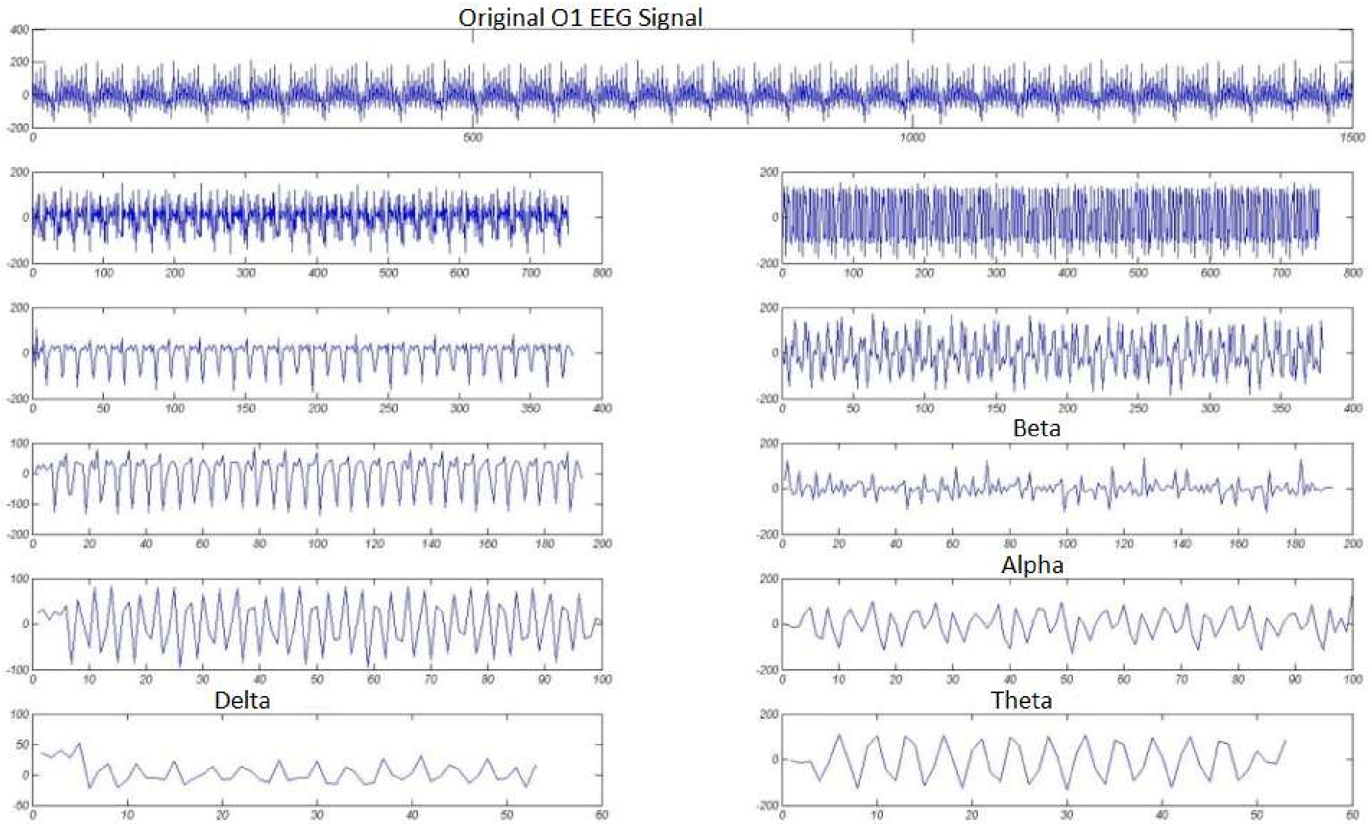


Figure 2: The O1 Original and Processed EEG Signals of a Left Handed Subject

The procedure of wavelet decomposition is shown in Figure 3. A signal x[n] is fed into two filters h[n] and g[n] respectively [10]. The filter h[n] is a high pass filter and the filter g[n] is the low pass filter. After the signals pass through the filters, they are down-sampled by the factor of 2. The signal that passed through the high pass filter and the down-sampler is the level 1 detailed coefficient D1 while the signal that passed through the low pass filter and the down-sampler is the level 1 approximate coefficient A1. From A1, the process is repeated for level 2, level 3 and so on, undergoing even more decomposition. This means that the second level detailed coefficient D2 is derived from the approximate coefficient A1.

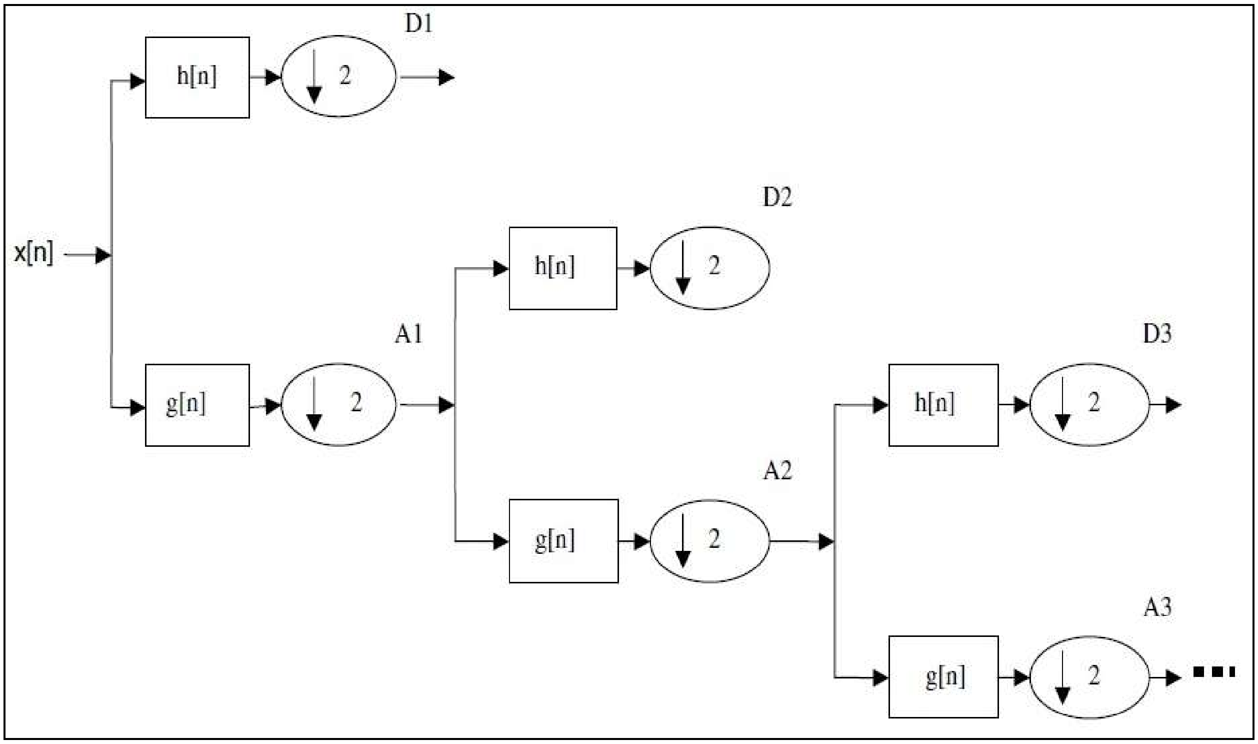


Figure 3: The Procedure of Wavelet Decomposition.

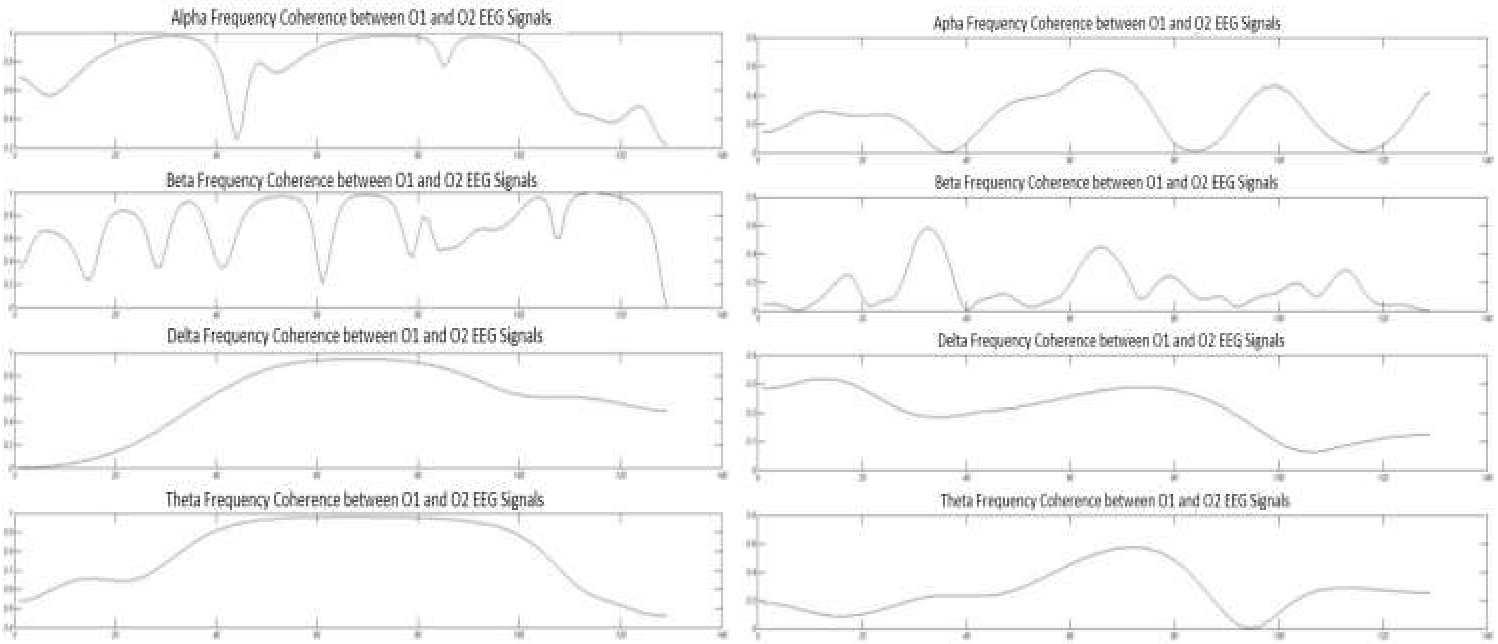
4.2 Analysis on the Mean EEG Coherence

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 alikeness 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.

Table 4: Mean EEG Coherence for a Left Handed Subject and a Right Handed Subject

Subject Handedness	Mean EEG Coherence
Left	0.721115
Right	0.219505



(a) (b)

Figure 4: The Coherences for the Four Types of Wave of (a.) Left-Handed Subject and (b.) Right-Handed Subject. From top to bottom are Alpha, Beta, Delta and Theta.

Based on the above table, in which the mean EEG coherence is obtained from one left-handed subject and one right-handed subject, it can be said that generally left handed subjects have higher mean EEG coherence than right handed subjects. Left handers have larger corpus callosum (CC) than right handers, discovered by either postmortem or using Magnetic Resonance Imaging (MRI) [13, 14, 15]. It is due to this that the Mean EEG Coherence of the left handed subject is higher. The corpus callosum represents the major commissural tract connecting the two cerebral hemispheres and is supposed to play crucial integrative role in functional hemispheric specialization [14]. Left handers, having bigger corpus callosum areas and better inter-hemispheric communication, excel in many areas and fields especially those required less lateralization.

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	$TL + FR = 4$	$FL + TR = 4$	$N = TL + TR + FL + FR = 8$

An explanation is indeed needed to clarify the meaning of the abbreviations and values in Table 6. *TL* is the true left handed subjects who are determined as left hander. *FL* is the true right handed subjects who are determined as left hander. TR is the true right handed subjects who are determined as right hander. FR is the true left handed subjects who are determined as right hander. The sum of *TL* + *FL* is the total number of subjects determined as left handed. The sum of *TL* + *FL* is the total number of subjects determined as right handed. The sum of *TL* + *FR* is the total number of subjects who are truly left handed. The sum of *FL* + *TR* is the total number of subjects who are truly right handed. *N* is the total number of subjects in this study. Diagnostic accuracy or simply accuracy can be calculated using the formula

$$Accuracy = \frac{(TL+TR)}{(N)} = \frac{(3+4)}{(8)} = 0.875 \tag{4.1}$$

The result of the calculation above shows that the accuracy of this handedness determination system is 0.875 or 87.5%. This value was still acceptable but due to the fact that the handedness of the subjects is known, a better result should have been achievable.

4.4 Mean EEG Coherence Midpoint Value Adjustment

The mean EEG coherence midpoint to separate the group of left handers with the right handers is set as default which is 0.5 as there is definitely a need of change as an improvement to the system. The new mean EEG coherence midpoint is set as the mean of all the eight mean EEG coherence which is 0.457672. It was calculated by adding all eight EEG coherence values and then divided by eight. Based on Table 5, all of the determined handedness remained the same with this midpoint except for the target L3. Table 7 shows a new result based on the new midpoint with the highlighted objects which are affected by the new midpoint.

Table 7: Mean EEG Coherence for a Left Handed Subject and a Right Handed Subject with Adjusted Midpoint

Subject Handedness	Subject Code	Mean EEG Coherence	Determined Handedness
Left	L1	0.721115	Left
	L2	0.625675	Left
	L3	0.492867	Left
	L4	0.667909	Left
Right	R1	0.219505	Right

	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.

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