Offline LabVIEW-based EEG Signals Analysis for Human Stress Monitoring

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Abstract*—Stress is often known as a state of mental or emotional tension resulting from adverse or demanding circumstances. People nowadays are faced stress and different people will have different level of stress and it might be difficult to analyse. Hence, EEG technology is invented to assist people to determine the level of stress by using brain signals. Thus, this paper describes the development of a LabVIEW-based system that can determine the level of stress based on the analysis of brain signals in LabVIEW. In this study, 1-channel EEG amplifier are employed to record EEG signals from five subjects at three different cognitive states which are closed eyes (do nothing), playing game and doing IQ test. The eegID application in mobile phone is used to capture recorded EEG signals from EEG amplifier and then the EEG signals are transfer to computer through Bluetooth for analysis which involves noise filtering, power spectrum conversion, features extraction and classification stage. The result shows that the average centroid which was applied on the EEG Power Spectrum of Alpha band is higher than Beta band when subject is at relax cognitive state meanwhile the average centroid of EEG Power Spectrum of Beta band is higher than Alpha band when subject is at stress cognitive state. Thus, it can be concluded that the subject are in the stress cognitive state when playing game and doing IQ test. At the end of this project, the LabVIEW Graphical User Interface (GUI) is created to display the level of stress for each subject after undergoing several mental exercises. Beside LabVIEW GUI, a device is constructed to display the level of stress in offline manner.

***Keywords*—stress; EEG, LabVIEW; Alpha band, Beta band power spectrum; average centroid; offline**

I. Introduction

Electroencephalogram (EEG) is a measurement device used for monitoring and measuring the different electrical activities in the brain [1]. Different types of electrical activities correspond to different states of the brain. Every physical activity of a person is due to some activity in the brain which in turn generates an electrical signal. These signals can be captured and processed to get the useful information that can be used in early detection of some mental diseases such as stress [2]. Everyone experiences stress in life. Moderate stress can be beneficial to human; however, excessive stress is harmful to the health. Stress is also the major risk factor for the occurrence of heart attack, hypertension, strokes or even sudden death is also caused. To monitor stress, different methods can be used [3-6]. In this project, EEG signals or brain signals is used to determine the level of stress. EEG signal is divided into five frequency bands which are Delta, Theta, Alpha, Beta and Gamma and the each EEG frequency band and its related activities are shown in the Table I.

TABLE I. EEG Frequency Band and Activity

Band	Frequency	Activity
Delta	0.5 - 4 Hz	Deep Sleep
Theta	4 - 8 Hz	Drowsiness, Light Sleep
Alpha	8 - 13 Hz	Relaxed
Beta	13 - 30 Hz	Active Thinking, Alert
Gamma	More than 30Hz	Hyperactivity

Then, the EEG signals are analysed using LabVIEW software and identify the unique features to monitor human stress level. LabVIEW is graphical programming environment which consists of a Block Diagram and a Front Panel. The Block Diagram provides a graphical code development environment whereas a Front Panel allows the user to interact with a VI. LabVIEW programming is chosen because it provides an efficient and easy-to-use environment for code development especially when the user needs to interact with the program and visualize the results [7-9]. Throughout this project, the analysis of EEG signal will provide alertness to people about the level of stress.

Hence, the main objective of this research is to design an offline stress level recognition system using EEG signals and LabVIEW. In order to achieve the main objective, several sub-objectives need to be implemented such as to develop LabVIEW coding to analyse and extract EEG features from EEG signal that related to stress and to construct the LabVIEW Graphical User Interface (GUI) and a device to display the level of stress.

II. Methodology

The research focuses on the development of LabVIEW coding and GUI to analyze human brainwaves and monitor the stress level. Thus, several steps are implemented to determine the level of stress as described below.

A. Subject Selection

5 subjects which consist of 2 males and 3 females which age range from 23 - 25 years old are chosen for this research.

B. Measurement Protocol

In this project, 1-channel Neurosky MindWave EEG headset as shown in Fig. 1 is selected to carry out the experiment. The headset is used to capture the brain signal with the sampling rate of 512Hz. The sensor tip of Neurosky is placed on the forehead of the subject and the ear clip is clipped onto the earlobe. When Neurosky is turned on, it will pair with the mobile phone by using Bluetooth technology as shown in Fig. 2. The apps that was used to record data is eegID application in mobile phone as shown in Fig. 3. Here, the EEG data information gathered from EEG amplifier is uploaded to drop box in mobile phone.

For measurement protocol, EEG data will be taken in 3 different human state conditions that is closed eyes, playing game (Word Search), and doing IQ test. Before the data is taken, let the subject at closed eyes or playing game or doing IQ test state for 30 second. After 30 second, the data start to taken for 5 minute and the EEG data is send to the drop box. Then, the EEG data is analysed using LabVIEW.

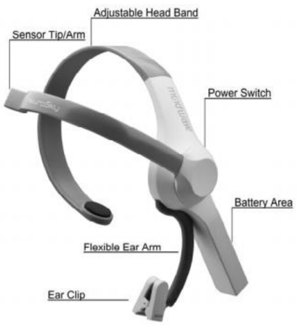

Fig. 1. 1-Channel Neurosky MindWave EEG Headset

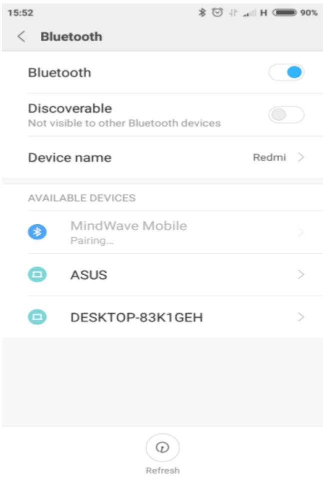

Fig. 2. Pairing Neurosky MindWave EEG Headset using Bluetooth

Fig. 3. EEG Apps in Mobile Phone

C. Feature Extraction

In this study, a Spectral Centroid of EEG signal is selected as the features in stress recognition. The Spectral Centroid is used to find the centre value of the groups for each EEG frequency bands. The Spectral Centroid is defined as the average frequency weighted by amplitudes, divided by the sum of the amplitudes and the formula is shown in Equation 1 [10-11].

$$C = \frac{\int xg(x)dx}{\int g(x)dx} \tag{1}$$

D. Measurement Process Flow

Fig. 4 represents the flow chart of this study. Firstly, five number of sample is selected which consists of 2 male and 3 females. Then, EEG data is taken by using the 1-channel NeuroSky Mindwave EEG headset for three states which are closed eye state, playing game state and doing IQ test state for five minute. Each of the samples is taking the EEG data for three times to get the average result. After collecting all the data from each sample, the data analysis is done in LabVIEW programming.

In this study, the Alpha band and Beta band is selected to analyse the human stress. The feature select in this project is spectral centroid of each Alpha and Beta band. The value of spectral centroid will determine to classify the level of stress of the sample. The spectral centroid can be employed to indicate the change in human cognitive after undergoing mental exercises [12]. When the centroid value of Alpha band is higher than the Beta value, the sample is in relax state. Meanwhile when the centroid value of Alpha band is lower than the Beta value, the sample is in stress state. For stress state, it is divide into two which is low stress and high stress. The threshold centroid value is set to 380. The threshold centroid value is determined according to the average centroid value of Beta band of all the data. Once the value of centroid value is higher than 380, the sample is said to be high stress and when the value of centroid value is lower than 380, the sample is said to be low stress. Next, the feature classification by using k-NN classifier is implemented to determine the accuracy of the selected EEG features. After that, GUI in the front panel of the LabVIEW programming and the hardware will display the level of stress will be displayed in the form of. Finally, the system is tested to make sure the overall system is run smoothly and perform well.

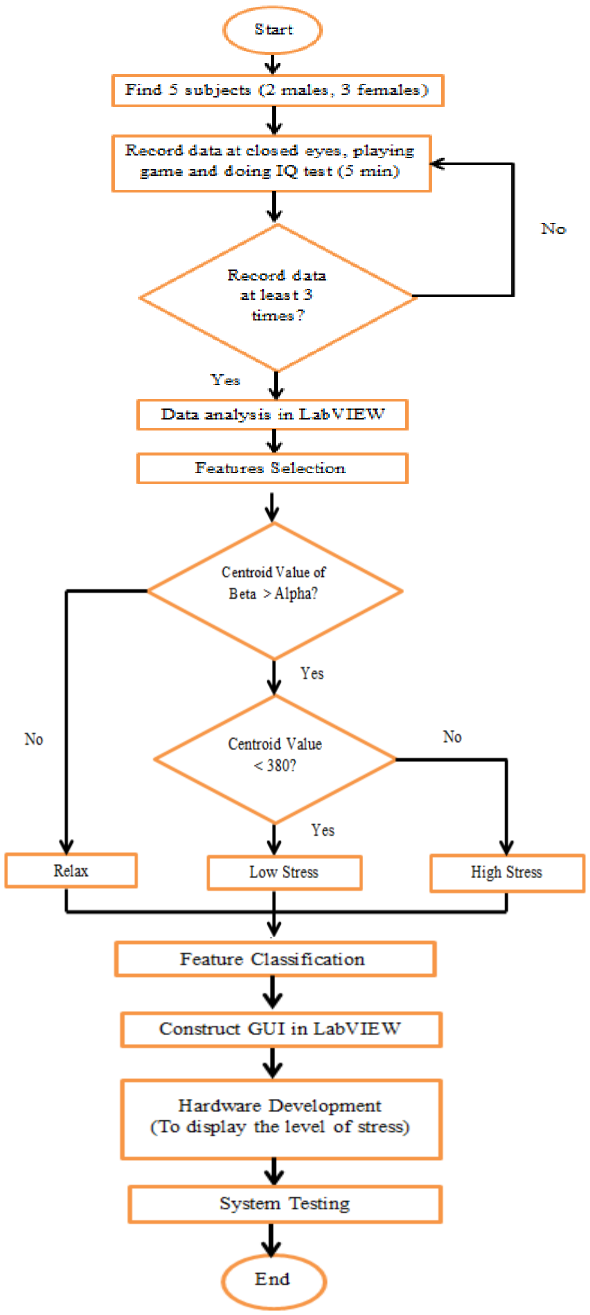

Fig. 4. Flowchart of the research

Fig. 5 shows the block diagram of this research. First, EEG signal is captured using the 1-channel Neurosky MindWave EEG headset. The 1-channel Neurosky MindWave EEG headset captured the signal from the forehead. The headset is paired with the phone by using Bluetooth technology. The apps that was used to record data is eegID apps in mobile phone and uploaded EEG data information to drop box in phone. After the EEG signal is taken, the raw EEG signals are used to analyse in LabVIEW. First, pre-processing is done to removal of noises. Once the pre-processing is done, next task is feature extraction. The frequency range relevant which is Alpha (8-13Hz) and Beta (13Hz-30Hz) are extracted. After that, the centroid values of EEG band are calculated and feature classification by applying KNN classifier to make sure the selected EEG features in the term of centroid of EEG power spectrum is accurate. Lastly, GUI and EEG-based stress recognizer are constructed to display the level of stress level.

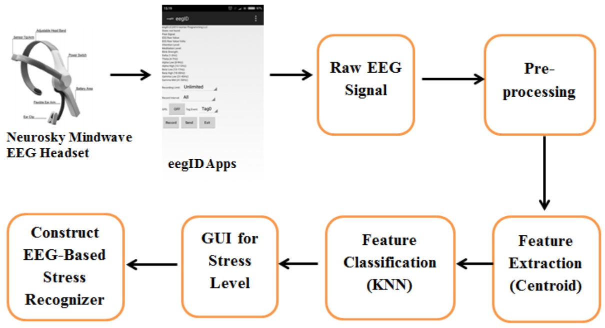

Fig. 5. Block diagram of the project

III. Results and Discussion

A. LabVIEW Programming

Fig. 6 represents the overall LabVIEW programming for the whole project. The LabVIEW programming consists of three parts which are importing data and Power Spectral Density (PSD), displaying the level of stress and LabVIEW Interface for Arduino (LIFA).

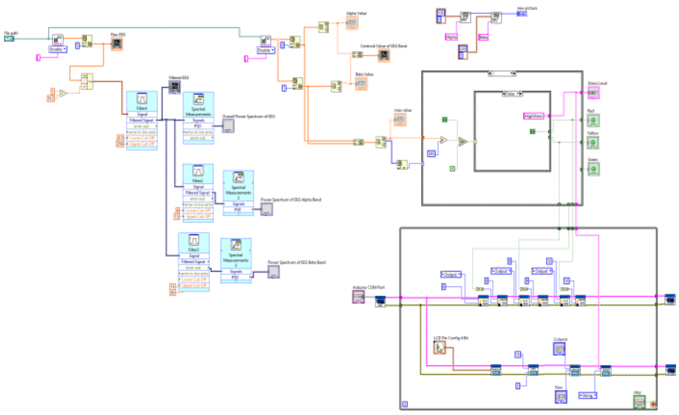

Fig. 6. The overall LabVIEW programming for the study

B. Graphical User Interface

The graphical user interface (GUI) is designed in LabVIEW to help user to communicate with the LabVIEW and display the results. Fig. 7 describes the overall LabVIEW GUI of the project. The GUI contains two main parts which are EEG signal processing and displaying the level of stress by using centroid value. In EEG signal processing part, it contain the graph of raw EEG, filtered EEG, overall power spectrum of EEG, power spectrum of EEG Alpha band and power spectrum of EEG Beta band. Meanwhile for the displaying the level of stress by using centroid value part, it contain the bar graph of centroid value of EEG band, value for Alpha and Beta band, indicator for stress level and three LED to indicate the level of stress. The GUI is tested and successfully run to display the level of stress as elucidated by Fig. 7.

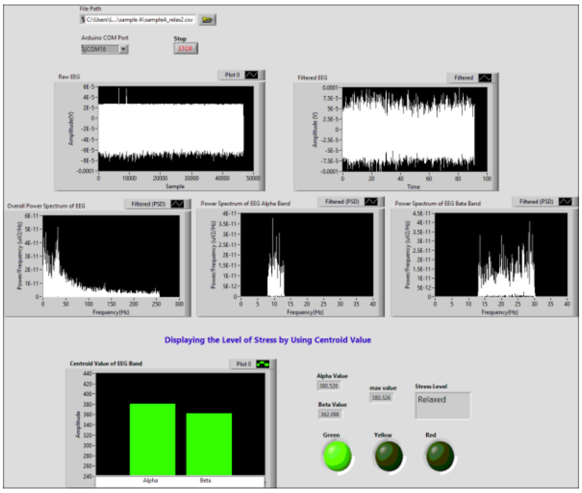

Fig. 7. The overall LabVIEW GUI of the project

C. EEG Signal Processing

The captured of the raw EEG signals are shown in Fig. 8. The signal is captured from the Neurosky MindWave EEG headset and then recorded by using the eegID apps. The data recorded is saved in the .csv file. The .csv file is containing the raw EEG data in term of voltage and it is important data for data analysing. After the raw EEG signal is plotted, the next process is pre-processing. The bandpass Butterworth filter is used to filter the noise of raw EEG containing the EOG, EMG or others noise and it is used to eliminate the unwanted signal. Fig. 9 shows the graph of filtered EEG signal after doing pre-processing process to remove the noise. Fig. 10 shows the graph of overall power spectrum of EEG signal. The overall power spectrum graph consists of five frequency band which is Delta, Theta, Alpha, Beta and Gamma band. The frequency range of the PSD is from 0Hz to 256Hz. This is because the sampling frequency of the 1-Channel Neurosky MindWave EEG headset is 512Hz. Hence, the maximum frequency will be half of the sampling frequency which has to obey Nyquist theorem to avoid aliasing to occur. Fig. 11 shows the power spectrum of EEG Alpha band and the Fig. 12 shows the power spectrum of EEG Beta band. The Alpha and Beta band is extracted from the overall power spectrum of EEG signal because Alpha and Beta band are important to analyse the level of stress.

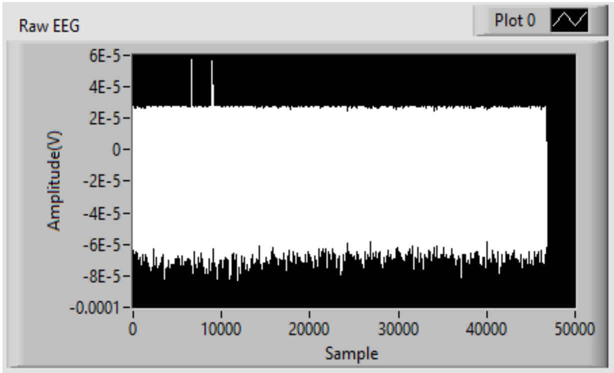

Fig. 8. Raw EEG signals

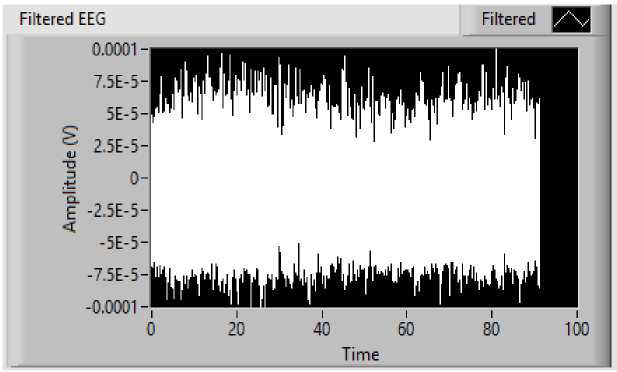

Fig. 9. Filtered EEG signals

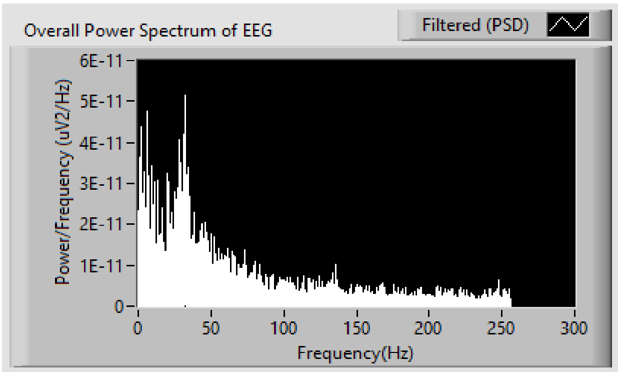

Fig. 10. Overall power spectrum of EEG signals

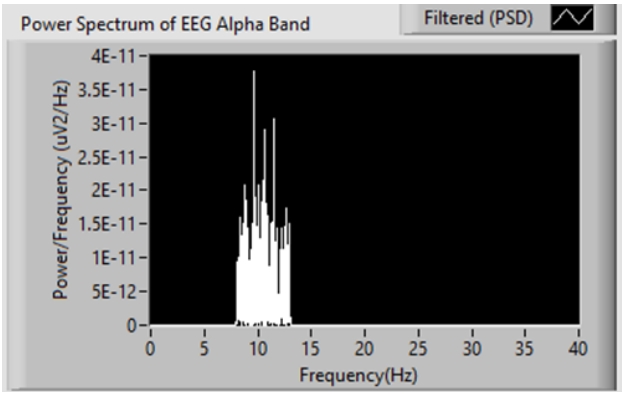

Fig. 11. Power spectrum of EEG Alpha band

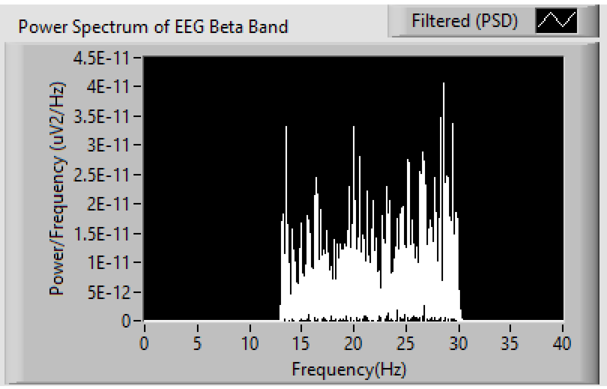

Fig. 12. Power spectrum of EEG Beta band

D. Hardware Design

Fig. 13 depicts the stress device indicator which is constructed to display the stress level instead of displaying stress level in LabVIEW GUI. The hardware consists of Arduino Uno, LCD and LEDs. Here, the LCD component is used to display the stress level in term of relax, low stress or high stress. In addition, the LEDs act as indicator for stress level. For example, when green LED is turned on, it indicates relax state. Meanwhile, the yellow LED and red LED indicates low and high stress respectively. The blue LED is act as the indicator for LCD. From Fig. 7, it can be concluded that the subject is in relaxed mode because the LCD displayed relax state and the green LED will turn on.

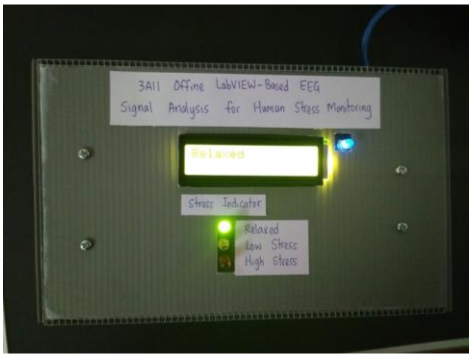

Fig. 13. Stress device indicator

E. Analysis of Centroid Value of EEG Signal

Table II indicates the centroid value for Alpha and Beta Band of five samples at three different states which are closed eyes, playing game and doing IQ test. Due to some inaccurate data in each state, total average centroid value is calculated to obtain a better result to analysis the level of stress for each state. Fig. 14 represents the total average centroid value against state for 5 samples. From Fig. 14, it can be concluded that the closed eye state is at relaxed mode, while playing game state is at low stress mode and doing IQ test is at high stress mode.

TABLE II. RESULTS OF CENTROIDS AT 3 DIFFERENT COGNITIVE STATES

Sample	State / Centroid Value / Data	Closed Eye		Playing Game		IQ Test	
		Alpha	Beta	Alpha	Beta	Alpha	Beta
A	1	368.6011	385.9534	377.0356	380.3682	341.838	362.5229
	2	380.5263	362.0982	280.8736	373.3955	378.5269	382.5584
	3	386.2923	381.3882	344.5353	360.5131	298.9571	380.7882
B	1	373.6264	346.189	364.0755	349.2838	395.4638	400.8955
	2	398.8933	384.5527	398.725	378.0505	369.4062	387.3779
	3	388.2525	380.8368	378.5514	363.562	380.4361	376.451
C	1	343.6597	387.9237	288.1139	394.7296	290.2953	376.323
	2	388.5786	335.9975	322.4222	342.3299	364.3106	372.985
	3	380.6125	365.8888	339.0375	366.2198	250.9758	353.5162
D	1	380.8082	347.7404	297.5708	382.0705	396.6376	384.1483
	2	371.6402	378.2879	297.7619	385.4448	401.8568	421.5076
	3	381.5113	371.992	313.4888	352.8998	307.0889	382.8013
E	1	420.0617	415.1453	295.3351	381.8468	369.7707	363.4808
	2	356.8683	408.8774	296.5597	374.2331	327.501	434.0975
	3	397.5566	313.3754	401.7069	409.2863	345.3304	421.8236
Average		**381.166**	**371.083**	**333.053**	**372.949**	**347.893**	**386.752**

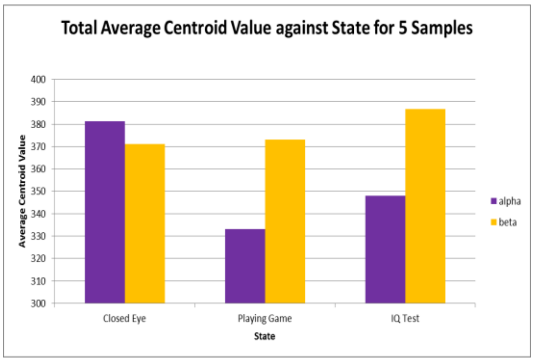

Fig. 14. Total average centroid value versus 3 cognitive states

Table III represents the summary of subject's state at three different cognitive states. When closed eyes, all sample are in relax state. For playing game state, three of them are in low stress, one sample is relaxed and one sample is high stress. Besides that, three of the samples are high stress and two samples are low stress when doing IQ test. The states of playing game and doing IQ test cannot obtain the same result is due to the fact that different sample can have different of emotional reaction or state when handling game or IQ test. For example, some of the sample might feel that game is able to give them a relaxing feeling while some of them might have different feel. In fact, game and IQ test will carry out different results that depend on the feeling of the sample themselves. However, in overall, it can conclude that closed eye is relaxed mode, playing game is low stress and doing IQ test is high stress.

TABLE III. STRESS LEVEL AT 3 DIFFERENT COGNITIVE STATES

Sample	State		
	Closed Eye	Playing Game	IQ Test
A	Relax	Low Stress	Low Stress
B	Relax	Relax	High Stress
C	Relax	Low Stress	Low Stress
D	Relax	Low Stress	High Stress
E	Relax	High Stress	High Stress
Overall	Relax	Low Stress	High Stress

F. *Feature Classification*

For the features classification results, Fig. 15 depicts the classification accuracy at different percentage of training and testing ratio. When the ratio of training vs testing data is set at 50:50 ratios, 60:40 ratios, 70:30 ratios and 80:20 ratios, the percentage of accuracy is 54.17%, 55.56%, 66.67% and 77.78% respectively. The highest classification rate is obtained at 80:20 ratios training versus testing. Hence, it can be concluded that 80:20 training vs testing ratio is the best among these four ratios and the selected EEG feature in term of centroid value is suitable to indicate the level of stress.

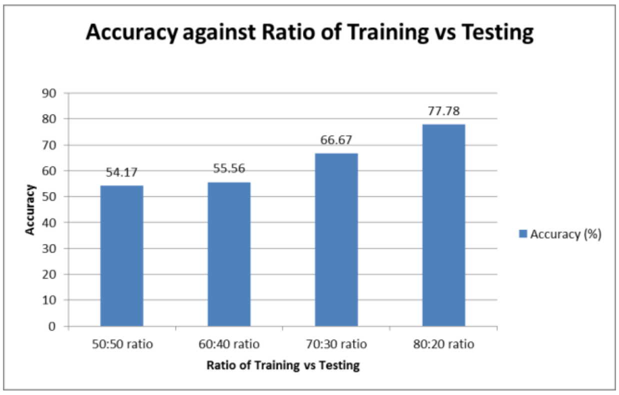

Fig. 15. K-NN classification results at different ratio of training versus testing

IV. CONCLUSIONS

The offline stress level recognition system is successfully implemented to detect the level of stress based on EEG signals. The LabVIEW coding is developed and it is successfully run to analyse the EEG signal and centroid value of Alpha and Beta band of EEG signal is extracted to analysis the stress level. From the experiment result, when the Alpha is higher than Beta, the sample is at relaxed mode while the sample is at stress mode when the centroid of Beta is higher than Alpha. But, the stress mode is divided into two levels which is low and high. Low stress is the centroid value less than threshold value, 380 and high stress is the centroid value more than threshold value. Although there is some data not follow the pattern of EEG signal, but it can further improve by obtain more data to increase the accuracy. Besides that, the LabVIEW GUI and offline stress level recognition or device is successfully constructed to display the level of stress. Lastly, a standalone wireless stress recognizer is constructed in the future work without depend on LabVIEW platform to run the system.

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