Short Message Service Application by Using Brain Control System and Support Vector Machine (SVM) on Single Channel Electroencephalography (EEG)

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***Abstract*—Most people who suffer from physical and sensory disabilities have limited activities. They need communication tools to facilitate communication activities with others. The purpose of this research is to create an application that translates thoughts to text which will be implemented in SMS feature by taking raw EEG from Emotiv EPOC, filtering, and applying machine learning algorithm, which is Support Vector Machine. There are two research steps: analysis and implementation. In the analysis step, the EEG samples taken from respondents are used for analyzing the most dominant channel. Then, EEG signal extraction uses Emotiv EPOC SDK, filters EEG signal taken from the most dominant channel and applies SVM algorithm for data training. C# based UI application is used as interactive media, so user can see the extraction result. The result of this research is an application that translates human thoughts to SMS.**

***Index Terms*—EEG, Emotiv, Support Vector Machine, Brain Computer Interface (BCI).**

I. Introduction

In the last few years, technology has improved in a significant way along with the improvement of culture and people. These technologies are often used to solve problems which occurr in the life of human, starting from simple problem to a more complex one. As an example, the technology is used in health industries for a specialized or disabled person; it is the development of the application to translate brainwaves into texts. These technologies may not run without Brain Computer Interface (BCI), which is maintained in the last couple of years.

According to Vallabhaneni, Wang, and He [1], "Brain-computer interface is a communication method which moves according to neural brain activities and independent from the normal output of muscle". Communication technology using BCI is one of the important factors to create an application that takes brainwaves by interaction between a user and a system outside keyboard (Van Erp, Lotte, and Tangermann [2]). The signal produced from brain's neuron is recorded, processed, and produced as an instrument for the computer system.

The application which translates human's brainwaves into texts is developed using library Emotiv SDK for developing control system. Support Vector Machine (SVM) is used as machine learning, with hope it can extract the result in a fast response.

Some of the brainwave's signals which are recorded using EEG:

Table 1
Brainwave's Signal Recorded using ECG

Signal	Amplitude Range		Frequency Range (Hz)	
	From	To	From	To
EEG	2 µV	100 µV	0.5	100
EEG (EP)	0.1 µV	20 µV	1	3000
EOG	10 µV	5 mV	0	100
EMG	50 µV	5 mV	2	500
ECG	1 mV	10 mV	0.05	100

Some of the previous researches look into the applications that use EEG: Wahed, Islam, and Biswas [3] study a letter recognition system with FFT, statistical analysis and wavelet analysis as the most dominant feature. Another research is from Michahial, Ranjith, Hemath and Puneeth [4], with speech synthesizer and feature extraction using Euclidian distance and neural network. These researches are used as our based to conduct our own research and implementation to send messages using EEG.

The main purpose of this research is to create an application that translates brainwaves into texts with fast data extraction, and to implement it into SMS features.

II. Materials and Methods

This research has 2 main components which are the use of neuroheadset as media to record EEG signal from user, and a desktop application to store EEG signal from neuroheadset.

Figure 1 is a block diagram that contains raw EEG acquiring, raw EEG preprocessing, training, classification and implementation. For raw EEG acquiring, we use neuroheadset which is connected with desktop application. The result of EEG taking will be processed by using digital signal processing and applying statistical analysis. Then, it will be implemented into machine learning for training step and classification.

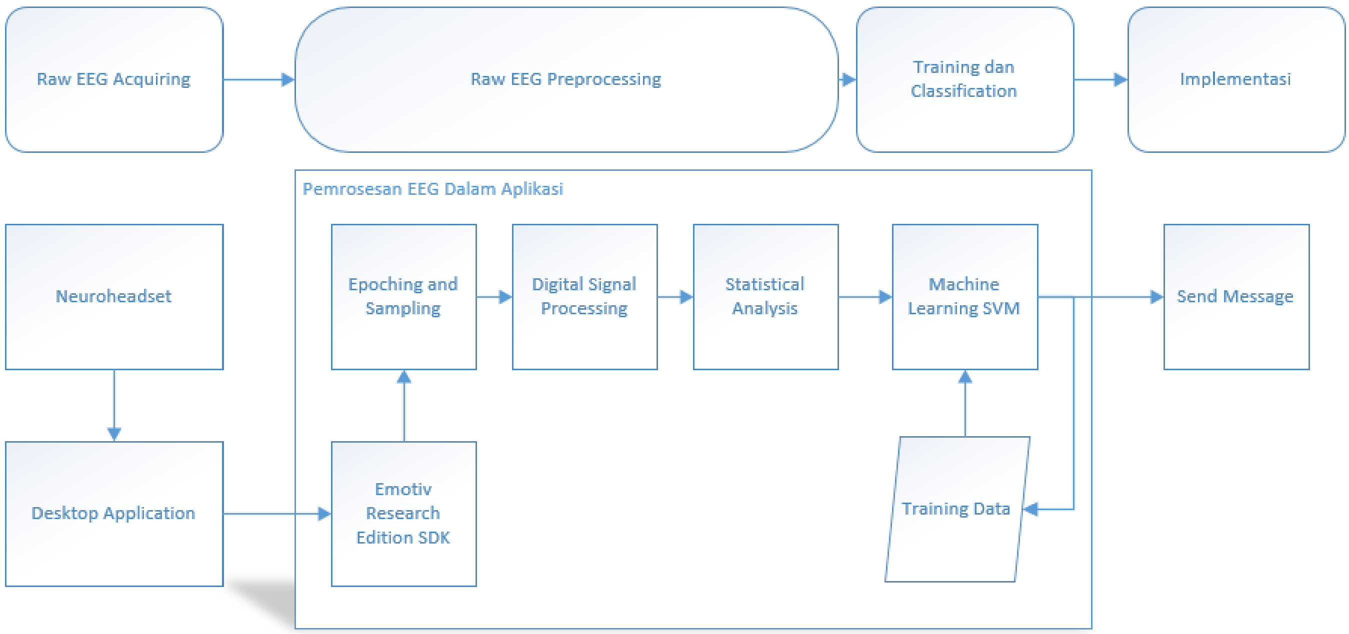

Figure 1: Block diagram of the system

A. *EEG Signal Acquisition*

In this research, the scientist use Emotiv Epoc Research Edition SDK [5] to obtain 14 EEG channels with sampling rate of 128 Hz. Emotiv Epoc Research Edition SDK provides access to raw EEG signal data, so that scientist can process the obtained signal. Furthermore, Emotiv Epoc Research Edition SDK also provides easy to use classes to detect brainwave, facial expression, eye motion, and emotion level. The scientist uses pariental brain, which contains imagination and memory, to obtain raw EEG signal data.

B. *Digital Raw EEG Signal Processing*

In processing raw EEG signal data, the researcher uses the digital signal processing [6]. The results are used as the input for machine learning. Emotiv Epoc Research Edition SDK contains 128 Hz sampling rate in every channel. For optimal signal quality, the theory of Nyquist and Shannon are often used, because the sampling rate can be expanded into 2 times from the frequency analog signal, which is converted into discrete signal. This expansion to 2 times of frequency analog signal is used to decrease the occurrence of bad effects and aliasing. After the analog signal is converted into a discrete signal, then filter to unneeded frequency using bandpass filter is needed. Bandpass filter is a filter that allows signal inside a frequency range. In this research, the researcher uses alpha and beta wave in range of 8 Hz to 32 Hz.

Because Fast Fourier Transform (FFT) assumes frequency periodically, every discontinuity between the first sample and the last sample that is repeated causes an after effect spectrum or spectral leakage. To reduce the problems, the researcher uses the windowing function [7], which is the hann windowing to reduce the spectral leakage by softening the result in every discontinuity frequency. Results from FFT are used as an input data to decide features for statistical analysis:

- Max value
  Compare the highest value from EEG signal in every letter.
- Mean
  Obtain average score of data in every chosen channel in a letter.

$$mean = \frac{1}{N}\sum_{i=m}^{N}(f_i) \quad (1)$$

- Skewness
  Measure asymmetric of an EEG signal to mean.

$$skew = \sqrt{N}\,\frac{\sum_{i=m}^{P}\left(f_i - \bar{f}_i\right)^3}{\left(\sqrt{\sum_{i=m}^{P}\left(f_i - \bar{f}_i\right)^2}\right)^3} \quad (2)$$

- Kurtosis
  Calculate pointed of an EEG signal to mean.

$$kurtosis = N\,\frac{\sum_{i=m}^{P}\left(f_i - \bar{f}_i\right)^4}{\left(\sum_{i=m}^{P}\left(f_i - \bar{f}_i\right)^2\right)^2} \quad (3)$$

- Standard deviation
  Standard deviation used to measure EEG signal data.

$$stddev = \sqrt{\frac{1}{N-1}\sum_{i=m}^{N}\left(f_i - \bar{f}_i\right)^2} \quad (4)$$

where, m as starting index, P as last index from data, N=(p-m) as total data.

The usage of statistical analysis is to increase the accuracy in character classification, because with only FFT, the pattern which is obtained is not enough to gain a dominant accuracy in character classification.

C. *Classification using SVM*

The researcher uses support vector machine algorithm as machine learning. In general, SVM [8] will find the best hyperplane which function as a divider to 2 class between input areas. In this research, the researcher is trying to find some of the best channels that are used as a deciding factor in character classifier. The candidate channels are P8, T7, T8, O1, O2 and FC6.

The best channel is obtained from the result of EEG signal that is processed through FFT. The signal result can be seen from linearly separable method, so that conclusion can be made on which is the candidate channel for character classifiers.

III. Result and Discussion

In this research, the researcher uses EEG data with sampling rate 128 Hz with 14 channels in 100ms. In 100ms, the system records 48 sample data for every character. Emotiv EPOC Research Edition SDK provides classes that can be used to access raw EEG signals. The researcher uses only EEG signals to recognize letters. Bandpass filtering, windowing function, FFT, statistical analysis and SVM as machine learning are also used in this research as character classifier method (supervised learning).

In this research, the researcher concludes to use only 1 channel for character classifier. This channel is decided from the result of EEG signal that has been processed through FFT. Figure 2 is the result of EEG signal filtered by FFT. Determining the best channel is seen as a linearly separable method with data test results. In the early test using 2 and 3 channels at the same time, the accuracy obtained is only 20-30%. Then the researcher tries testing with 1 channel. After a few tests, the researcher decides to use P8 channel, because this channel provides a better accuracy than the other channels.

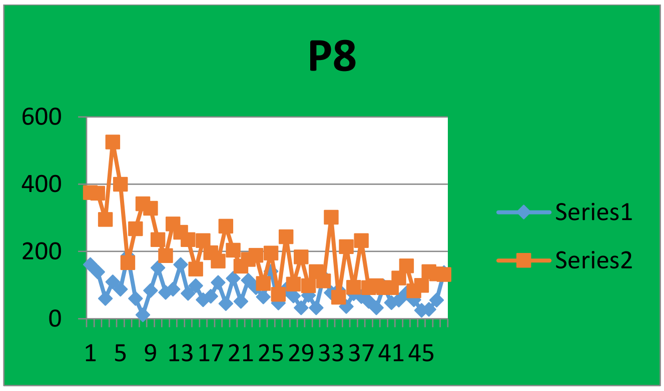

Figure 2: EEG sample from channel P8

Figure 3 is one of the interface systems that trains the data from the user, while Figure 4 is the application testing by the user. This research is tested on 5 respondents; each of them has different age, gender and disability, including the environment condition from quiet to noisy. Each 5 respondents is tested 5 times, with each testing tests on 10 characters at random. For every character, the respondents must imagine that they are writing the character according to visual image.

Table 2 and 3 show results of user testing by implementing only FFT and the combination of FFT and statistical analysis. The test results show that statistical analysis improved character accuracy from 29.6% to 59.2%.

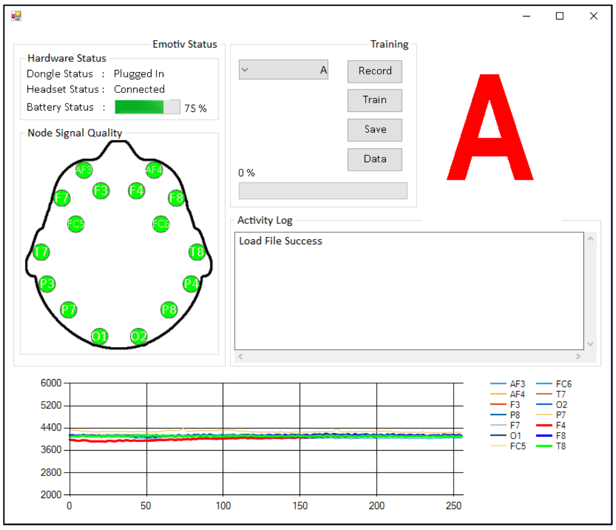

Figure 3: System's interface for data training

Figure 4: User Testing

Table 1
Testing result by using FFT

Respondent	Environment Condition	Test (%) 1	2	3	4	5	Ratio (%)
1	Quiet	30	40	20	30	30	30
2	Noisy	20	30	20	20	30	24
3	Quiet	50	30	30	40	40	38
4	Noisy	20	20	40	20	30	26
5	Noisy	10	30	40	30	40	30
	Average						29.6

Table 2
Testing result by using FFT and Statistical Analysis

Respondent	Environment Condition	Test (%) 1	2	3	4	5	Ratio (%)
1	Quiet	70	50	60	60	80	64
2	Noisy	80	40	50	70	60	60
3	Quiet	80	60	70	50	60	64
4	Noisy	50	60	50	70	60	58
5	Noisy	50	60	40	40	60	50
	Average						59.2

IV. Conclusion

From the research results, the application development uses only EEG signal, and the channel used is only P8. Results of raw EEG signals are processed into digital signal processing: bandpass filter, windowing function and FFT. FFT results are implemented into statistical analysis to obtain more accurate results. The use of P8 channel is obtained from series of tests which are analyzed by the linearly separable method for every EEG signal that has been processed through FFT. From the test results, only uses FFT will earn 29.6% of accuracy. Using FFT and Statistical Analysis will earn accuracy 59.2%. To obtain a better accuracy, the user is needed to be focused. The user's mental condition also needs to be fit.

For future research, a research on other channels in neuroheadset should be conducted, and the wavelet analysis method should be adopted for better accuracy. It is stated in the research (Wahed, Islam, & Biswas [3]) that the use of wavelet analysis has higher accuracy results than FFT and statistical analysis. Other machine learning algorithm should also be used to increase the speed and accuracy for classifier, and the audio headset should also be used to help focus on the visual usage.

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