Emotion Stress Detection using EEG Signal and Deep Learning Technologies

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Abstract

Brainwave reflects the change in electrical potential resulting from the conjunction between the thousands of brain neurons. A neuron can receive signals from other neurons and starts off cyclic discharge reaction when sufficient energy is accumulated. That is also the reason why people persistently emit brainwaves. According to experts from Laboratory of Brain Recognition and Behavior, Michigan University, long-term multitask operation results in the lack of efficiency and in filtering out irrelevant signals leads to the distraction of paying attention of the irrelevant message rather than work-related information. As a result, one would have problems in the transition from one job to another. However, for some people rely on their brain to deal with many things and it may lead to fatigue. Therefore, we did this experiment and tried to figure out the most efficient way to soothe the spiritual pressure and calm the mind down. We utilize deep learning as learning method to predict user's stress feeling through listening to the music. Through above research, by listening to music or create the atmosphere of a music background also with an artistic performance could provide not only psychological treatment effect but also improve the ability of the person to focus.

Key words: Brainwaves, Emotion Stress Detection, EEG, Deep Learning.

Introduction

IoT is becoming a favorite research topic due to the rapid advances in the network technologies and the increasing scope of IT applications. With the growth of social media and big data environment, researchers have enrichment data to support IoT development process. Meanwhile, the demand for high-performance computer systems is getting higher and higher to hope that the computer can bring us a good quality of life. Brainwave reflects the change in electrical potential resulting from the conjunction between the thousands of brain neurons [1] [2] [3]. A neuron can receive signals from other neurons and starts off cyclic discharge reaction when sufficient energy is accumulated. Deep learning is one of the methodologies can be used to calculate the emotional factors [4] [5]. In this paper, we will propose an alternative approach to utilize deep learning capability through brainwaves as features to enhance deep learning operation. We develop a system which could collect multi-users' brainwaves at the same time. The system could reduce the variables and research time. Then, we discuss the influences of music and brainwaves user's spirit. Especially, we emphasize to discuss the alpha wave; we separate it into two part, high alpha, and low alpha. Through the sensor that attached on the forehead, the MindWave Mobile can measure the modes and frequencies of biological electro-signals which is gotten from brain neurons [6] [7]. The sensor is attached to the prefrontal lobe which helps us comprehend and judge, as well as determining our behavior. Prefrontal lobe becomes particularly important when it comes to the moment that a person's thinking abilities such as attitude, emotion, and behavior, are required to be monitored. We found that music can make α wave energy rise which makes concentration can be improved.

Related Work

Before we implement music, we should go through the stress scale measuring subjective assessment of mental status test for the tester, also need to pay attention to environmental considerations and so on. As a basic reference for the impact of psychological factors, the stress roughly divided into external stress and internal stress factors [8].

External stress: this physiological stress source comes from external factors and environments such as inappropriate temperature, humidity, lighting, space and noise and other stimuli. Long-term effects will lead to human physiology unbearable and affect the emotions and behavior.

Internal stress: this physiological stress source comes from internal factors such as the need for a certain period for sleep and rest, need reasonable nutrition, the need for appropriate exercise, psychological needs, physical and mental needs. If for long-terms this need could not be met, the behavior of motivation could not be achieved. This will have a strong setback feeling, a sense of failure and internal pressure increases, and finally a series of psychological problems.

In different sensory states, healthy people will show different frequencies of brainwaves. These rhythmic brainwaves are often influenced by actions and thoughts and have specific reactivity [9]. The EEG is the most commonly used fundamental wave to describe the brain frequency band division and the different types of brainwaves that reflect brain mental states. According to the technical documents provided by NeuroSky[10] and the International Federation of Clinical Physiology for Clinical Neurophysiology[11], brainwaves are issued by physiological signals. Fig. 1 is the Alpha, Beta, Theta, Delta waveform legend. Based on the frequency ranges, brainwaves are classified into five categories:

(1) Delta activity (δ wave): The frequency is below the 3 Hz brainwave band. The amplitude is about 20-200μV. In a sober state, usually occurs when sleeping and not easily awakened, or under deep anesthesia or hypoxia, or with brain lesions in patients.

(2) Theta activity (θ wave): The frequency is between 4Hz and

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7 Hz. In general, it is a smaller amplitude. Mainly occurs in a child's top lobe and temporal lobe (temporal region). When adults are under emotional pressure a small number of Theta waves will appear. However, there is no regular type, and they may occur in a sleepy or highly relaxed sleep state. This band will be very obvious. Many other brain disease patients' exhibit θ waves.
(3) Beta activity (β wave): The frequency is 13 Hz or more, but rarely higher than 50 Hz. Studies have shown that Beta waves are influenced by tactile, auditory, and emotional stimuli and controlled by self-effort.
(4) Alpha activity (α wave): The frequency is 8-13 Hz, and the amplitude is about 20-200μV. For most people, the brain Alpha wave generated in the sober, quiet and relaxed state. As long as close your eyes and relax, you can immediately improve the Alpha wave activities of the brainwave.
(5) Gamma activity (γ wave): The frequency is between 31 and 50 Hz. In recent years, researchers have found that this wave is related to user's attention, raising awareness, happiness, and reducing stress. The meditation has a connection with human cognition and perceptual activity which related to gamma wave [12] [13].

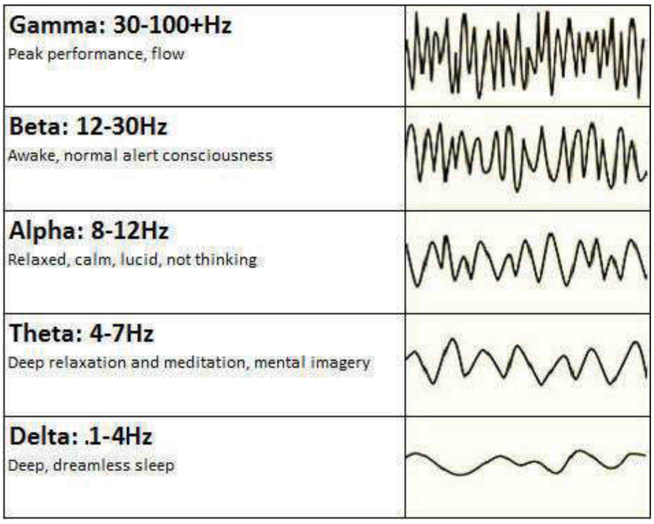

Fig. 1. The waveform of brainwaves [13]

Propose Methods

In this section, we will describe the system design and architecture. We also describe the methodology of the system.

Fig. 2 shows the system architecture. The system begins with EEG calibration for our NeuroSky Mindwave Mobile to get brainwave raw data. We prepare one-minute calibration to let the test subject stabilize the environment. In the next 10 minutes, we will let the test subject listen to the music. While the test subjects listen to the music, the system captures their brainwave EEG signal and save to the database. NeuroSky Mindwave Mobile provides an API to extract the EEG raw data into EEG brainwave frequency automatically.

Fig. 3 shows the system measurement flow to capture the brainwave signal. Neurosky Mindwave mobile using Fast Fourier Transform (FFT) calculates the frequency from analog to digitalize EEG data [6]. The equation of FFT is given in Equation 1.

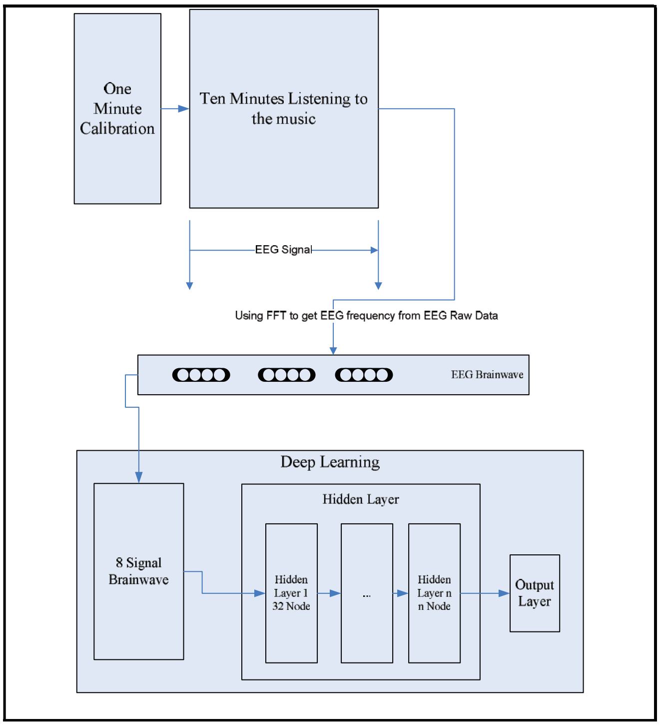

Fig. 2 The System Architecture

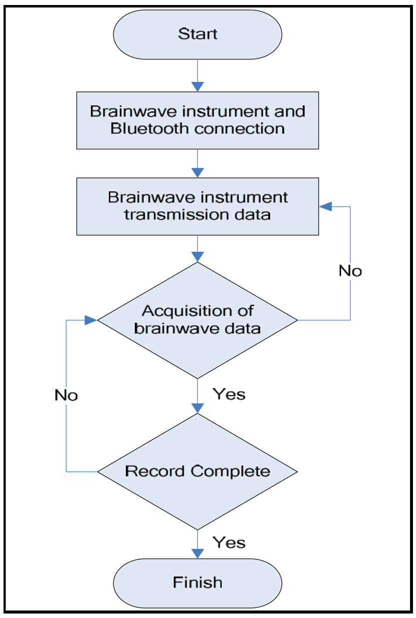

Fig. 3 Measurement Flow for Brainwave Signal

$$\mathrm{X}(k) = \sum_{k=1}^{N-1} x(n) W_N^{kn} : k = 0, \dots, N-1$$
$$W_N = e^{-i\frac{2\pi}{N}} \quad , \qquad (1)$$

where the value of *k* has *N* complex multiplications. A random signal usually has finite average power and is characterized by an average power spectral density as in Equation 2.

$$PSD_f(w) = \lim_{T \to \infty} \frac{\left|F_{X_T}(w)\right|^2}{2T} \qquad (2)$$

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where $|F_{X_T}(w)|^2$ represents the FFT signal output from test tester, and T represents the time of total input signal.

For the deep learning, the system implements a deep back-propagation network to predict the mental state of the test subjects from EEG signal data.

$$H_h = f(net_h) = \frac{1}{1+e^{-net_k}} \tag{3}$$

$$net_h = \sum_i W_{ih} \,. X_i - \theta_h \tag{4}$$

Back-propagation neural network has been widely used in machine learning research topics. The back-propagation network consists of the input layer (*X*), hidden layer (*H*) and an output layer (*Y*). Equation 3 is the computation of neural network between input and hidden layer. For every node in *X* which are connected to every node in H are calculated by Equation 3. Equation 4 calculates the sum of net_h for each node in the hidden layer. Theta is the bias of every node in the hidden layer. The process will be continuous until finish condition is reached.

$$Y_j = f(net_h) = \frac{1}{1+e^{-net_j}} \tag{5}$$

$$net_j = \sum_i W_{hj} \,. H_h - \theta_j \tag{6}$$

Equation 5 is the computation neural network of output layer and hidden layer. The process is similar to the computation of input and hidden layer. Every node in the hidden layer will be computed by Equation 6 and this process also repeated until the satisfying condition is reached.

Experiments and Results

The System's Dataset consist of brainwaves from 7 test subjects. Each test subject has 10 minutes of brainwaves by listening to the music. The system uses 80% data as training samples and the rest 20% as testing samples. Fig. 4 shows our brainwave frequency for sample test subjects listening 10 minutes of music. For every second of brainwave emitted from the brain, it also could emitted test's subject mental state. Fig. 5 shows mental state of the test subjects, as 1 is for attention and 0 for meditation. The system will use this data to predict the test subjects mental state from their emitting brainwaves.

Fig. 6 shows the system training and validation test for the dataset. The system deep learning's hyper-parameter setting as follows: Number of hidden layers is 7, with each hidden layer nodes are 32, 32, 16, 16, 16, 8, 8. The activation function is ReLU, and output nodes are 1. The system deep learning model is fully connected layers. In order to determine hyper parameter settings, we implement grid search, because the limitation of the page we only provide the best configuration in the paper.

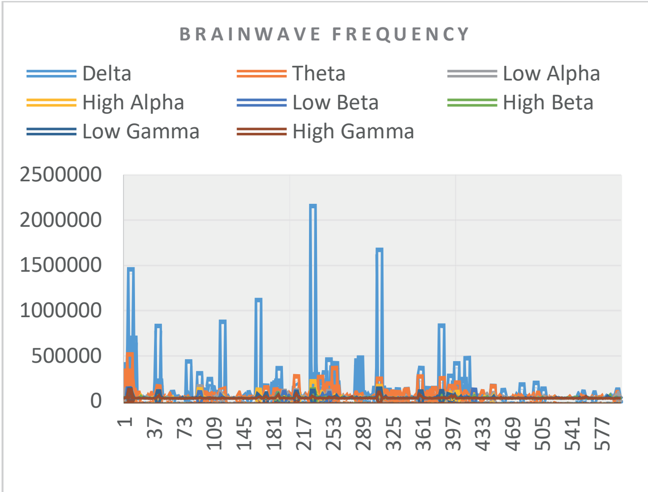

Fig. 4 Brainwave Frequency

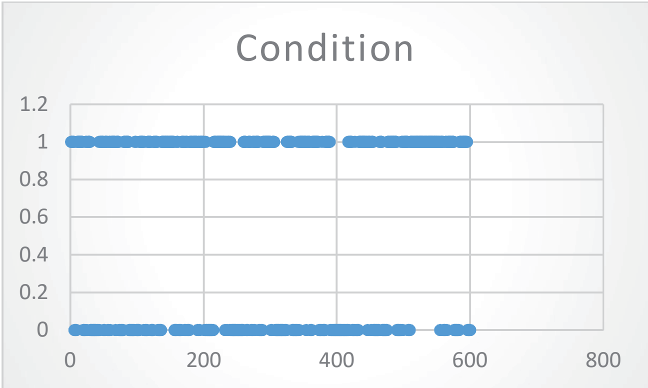

Fig. 5. Mental State of Test Subject (Attention and Meditation)

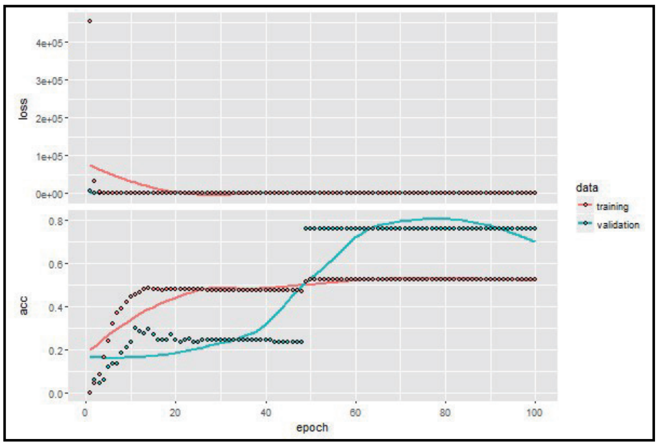

Fig. 6. Training and Validation Results

From Fig. 6 we could find the system deep learning model convergence quickly after 20 iterations. The system MSE loss value gets the best results on iterations 25 with loss value is 0.0882, the system best validation accuracy results is 80.13%.

We also compare our accuracy with F-score as shown in Table 1. We could find the system prediction for each class – 1(attention) and 0 (meditation). For each class, our system gets high precision for predicting class 0, and get a high recall when predicting class 1. The F1-score shows that our system is better in predicting class 1 than predicting class 0.

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Table 1. Accuracy Measurement by F-Score

Class	Precision	Recall	F1
1	0.4295	0.99610	0.6002
0	0.75	0.00874	0.0172

Conclusions

In this paper, we propose music frequency to detect emotion stress using brainwave and utilize deep learning. From experiment, our model could predict until 80% for test subject’s mental states. Our model has small MSE loss to 0.0882, it means our error will be smaller, and our validation loss is almost the same as our model training loss which means our model doesn’t face over-fitting.

In the future, we will combine the attention and meditation as emotion stress detection with other activities. This necessary that attention and meditation have measurement mean rather than only calculated by the system. We will add button click action as a control for the action, if user attention is high it means their button’s click accuracy must be high and vice versa.

References

[1] G. F. Woodman, "A Brief Introduction to the Use of Event-Related Potentials (ERPs) in Studies of Perception and Attention," *Attention, Perception & Psychophysics,* vol. 72, no. 8, 2013.

[2] S. Helmreich, "Potential Energy and the Body Electric," *Current Anthropology,* vol. 4, no. 3, pp. 265-284, 2013.

[3] H. Thomson, "Alpha, beta, gamma: The language of brainwaves," 7 July 2010. [Online]. Available: https://www.newscientist.com/article/mg20727680-200-alpha-beta-gamma-the-language-of-brainwaves/. [Accessed 10 February 2018].

[4] P. Barros, G. I.Parisi, C. Weber and S. Wermter, "Emotion-modulated attention improves expression recognition: A deep learning model," *Neurocomputing,* vol. 253, pp. 104-114, 2017.

[5] H. M.Fayek, M. Lech and L. Cavedon, "Evaluating deep learning architectures for Speech Emotion Recognition," *Neural Networks,* vol. 92, pp. 60-68, 2017.

[6] W. Sałabun, "Processing and spectral analysis of the raw EEG signal from the MindWave," *Przeglad Elektrotechniczny,* vol. 90, no. 2, pp. 169-174, 2014.

[7] R. Maskeliunas, R. Damasevicius, I. Martisius and M. Vasiljevas, "Consumer-grade EEG devices: are they usable for control tasks?," *PeerJ,* vol. 4, 2016.

[8] J. Apesteguia and I. Palacios-Huerta, "Psychological Pressure in Competitive Environments: Evidence from a Randomized Natural Experiment," *The American Economic Review,* vol. 100, no. 5, pp. 2548-2564, 2010.

[9] J. D. Kropotov, Quantitative EEG, Event-Related Potentials and Neurotherapy, Academic Press, 2009.

[10] J. Katona, I. Farkas, T. Ujbanyi, P. Dukan and A. Kovari, "Evaluation of the NeuroSky MindFlex EEG headset brain waves data," in *Applied Machine Intelligence and Informatics (SAMI), 2014 IEEE 12th International Symposium on*, Herl'any, Slovakia, 2014.

[11] G. H. Klem, H. O. LuÈders, H. Jasper and C. Elger, "The ten±twenty electrode system of the International Federation," *Electroencephalogr Clin Neurophysiol,* pp. 3-6, 1999.

[12] J. Fella, G. Fernándezab, P. Klavera, C. E. Elger and P. Fries, "Is synchronized neuronal gamma activity relevant for selective attention?," *Brain Research Reviews,* pp. 265-272, 2003.

[13] C. Tallon-Baudry and O. Bertrand, "Oscillatory gamma activity in humans and its role in object representation," *Trends in Cognitive Sciences,* pp. 151-162, 1999.