Tan, S. C. et al. (Eds.) (2013). Workshop Proceedings of the 21st International Conference on Computers in Education. Indonesia: Asia-Pacific Society for Computers in Education

Electroencephalogram Analysis of Pseudo-Haptic Application for Skill Learning Support System

Hirokazu MIURA[a*], Keijiro SAKAGAMI[b], Yuki SETO[b], Shumpei AKO[b]
Hirokazu TAKI[a*], Noriyuki MATSUDA[a*] & Masato SOGA[a]
[a]*Faculty of Systems Engineering, Wakayama University, Japan*
[b]*Graduate School of Systems Engineering, Wakayama University, Japan*
* is-staff@sys.wakayama-u.ac.jp

Abstract: This paper describes the brain states analysis of pseudo-haptic application for the skill learning supporting system. The pseudo-haptic is a phenomenon in which the human perceives force by according differences between his/her real motion and its visual feedback. It is difficult to evaluate human cognition of haptic state only from the observation of human behavior. Therefore, to measure the biological signal of the brain, we have used electroencephalogram. We have evaluated the brain activity in the sensing tasks in order to make a comparison among the several states of the sensing of pseudo-haptic

Keywords: Pseudo-haptic, brain-machine interface, electroencephalogram, skill learning

1. Introduction

The learner would like to check his/her mastered skill level during his/her training. Therefore, it is necessary to feed back the current mastered skill level to the learner in the skill learning support system. The visual feedback is useful to check the skill level, and it has been used to present his/her motion and pose in the virtual reality (VR) system or the augmented reality (AR) system. When the learning support system teaches how much to make force or suggests the cautions of the skill by generating force in the skill behavior, the learner's force in his/her behavior must be able to be sensed. There are some Haptic Interfaces like as Phantom (Geomagic Touch, n.d.) and Spider (Sato, 2002) which have been used to generate force in these VR or AR systems. However these interfaces are expensive and used only in the laboratory.

While, there is a method how the learner feels haptic by a pseudo force generation device. We have felt that the mouse operation is heavier when its cursor moves slower than the user intention. This phenomenon is called "Pseudo-Haptic". When the operational object (cursor) moving speed is deferent from the simulated object behavior in the user's brain, the user feels the haptic as illusory perception (Crison, et al., 2004). The Pseudo-Haptic method is useful for the force feedback interface. The method is used easily and has cost advantage in order to generate haptic feedback. In the skill learning support system, the combination tool of the pseudo-haptic method and haptic devices as Phantom is able to teach complex force skill in the virtual space. However, it is difficult to evaluate the effect of pseudo-haptic for skill learning. Because the users feel the effect of visual force feedback subjectively, so there are individual differences of the effect of the learning system. Therefore, it is necessary to develop the evaluation method whether the learner recognize the pseudo-haptic and the learning support system's suggestion objectively.

2. Overview of Skill Learning Support System Using Pseudo-haptic

We have analyzed electroencephalogram of the learner who operates the device with pseudo-haptic phenomenon. We have tried to decide whether the learner feels haptic or not from electroencephalogram patterns. In the skill learning support systems, the visual feedback methods based on VR and AR are improved for the learners' self-recognition of their behaviors (Soga, M., Ishii, K., Nishino, T. and Taki, H., 2012). These systems make synthetic images from the learner's behaviors and the expert's ones in the virtual space. The learner watches the differences between his/her motion and the expert's one. However it is difficult to master the skill with force control from the virtual space which consists of motion and pose images. In the virtual space, the learner cannot feel the force of ball hitting in the baseball batting, playing tennis and so on. The pseudo-haptic makes sensing force like pressure in the virtual space by modifying motion images. So, we prose new system which uses pseudo-haptic (shown in Figure 1).

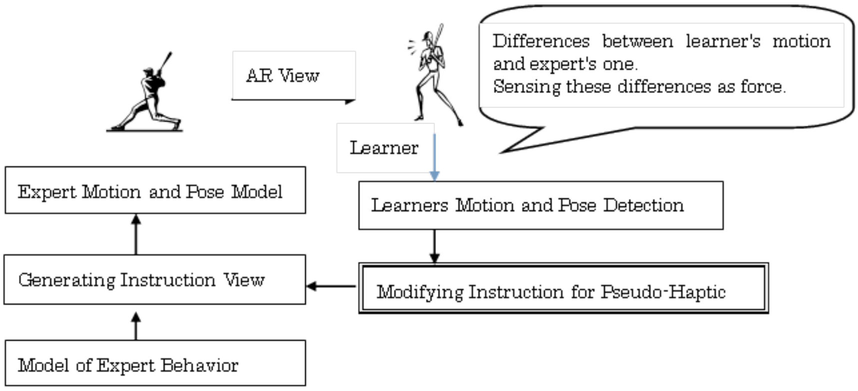


Figure 1. Skill Learning Environment.

2.1 Pseudo-haptic Phenomenon

The pseudo-haptic is a phenomenon of illusory perception which the human feel the haptic from the difference between his/her controlled mouse speed and the display its cursor speed. During the human is moving mouse in constant speed, the slower the cursor moves, the heavier he feels the weight of the mouse. The visual input of the mouse cursor behavior makes pseudo-haptic as if he/she feels reaction force against his/her hand (shown in Figure 2). This phenomenon is easy to generate, but the best ratio of input mouse speed and output cursor speed is calibrated before experiment.

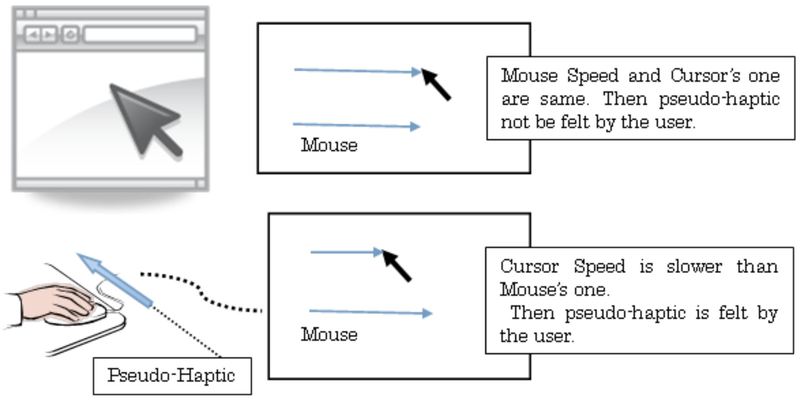


Figure 2. Pseudo-Haptic Generation.

3. Usage of Brain Machine Interface

3.1 Brain Machine Interface

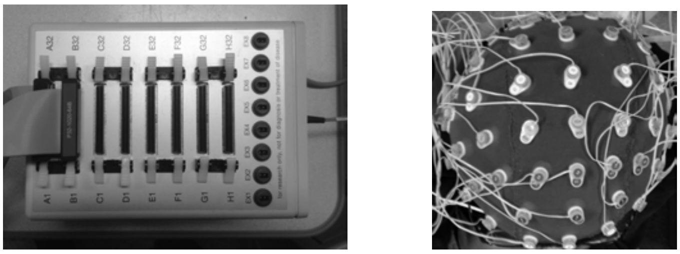
The BMI (Brain Machine Interface) is an interface which measures the human brain electrical activity or cerebral blood flow. It is able to use for the direct communication tool between the human brain and the machine. There are an invasive measurement type BMI and a noninvasive measurement type BMI. In the invasive measurement type BMI, measuring proves are inserted into the human brain directly. It can measure the brain activity with high accuracy, but the problem of ethicality and safety exists. While, the noninvasive measurement type BMI measures the cerebral activity to use scalp contacting head attachments. It is easy to measure the brain activities, but it is affected by noise of the volume conductor (skull and scalp) and the accuracy of data is lower than the invasive measurement type BMI's. Electroencephalogram (EEG) equipment is a kind of the noninvasive measurement type BMIs, and small size measure equipment. It has a high spatial resolution and is used most widely or frequently in a field of research. Our research also uses the EEG equipment to measure the cerebral activity when the learner works skillful learning tasks.

3.2 Electroencephalogram (EEG)

The minute signal electric current flows on the scalp in the several positions according to the cerebral activity connected with the brain. The EEG is a record which is measured neuron activities from some electric proves on the scalp. However, the minute signal electric voltage range is micro volt. It is difficult to measure the current, so the equipment amplifies this current by differential amplifier circuits which amplify a voltage of a difference between the signal of the reference point and the signal of the measuring point.

4. Brain Activity Measuring Experiment

We use the BioSemi Active Two system (Fig.3) to record EEG activity. The Active Two system has 64-channel proves and selects sampling rates which 2, 4, 8 or 16 kHz per channel. Instead of the mouse, we use the Sensable Technologies PHANTOM Omni (Fig.4) as cursor input device. We use the PHANTOM which does not generate any forces.



(a) ActiveTwo AD-box. (b) Electrodes in ActiveTwo

Figure 3. BioSemi ActiveTwo System.

Figure 4. Phantom Omni (Geomagic Touch).

4.1 Experiment

We have measured the following conditions:
The cursor has moved in normal and slow speed.

Task 1. PHANTOM stylus speed : Cursor speed in the display = 100 : 75
Task 2. PHANTOM stylus speed : Cursor speed in the display = 100 : 50

The subjects are 3 young men in their twenties.
Test Task: the subject traced the sphere as mark by the PHANTOM stylus. This sphere's speed is 6cm per second and it reciprocates in the horizontal direction. One trial consists of these 2 tasks. One test set

consists of 5 trials. The sequence of one task is 4 seconds rest, 7 seconds task and 4 seconds rest (Fig.5 and Fig.6).

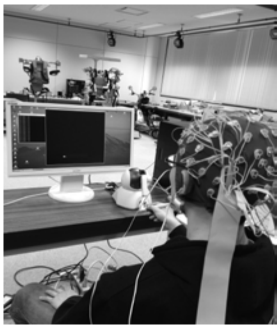


Figure 5. Experiment Image.

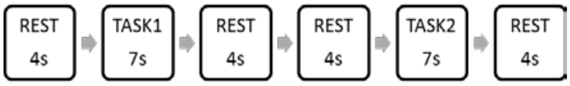


Figure 6. Test Sequence.

4.2 EEG Analysis

This section describes EEG analysis (Obana, H., et al., 2013)(Seto, Y., Ako, S., Kashu, T. et al., 2013)(Seto, Y., Ako, S., Miura, H. et al., 2013). We have selected alpha-wave and beta-wave range data by the band pass filer (8-30 Hz) to eliminate noise (Table 1). To acquire the frequency distribution specification of the wave data, we have used FFT (Fast Fourier Transform).

Table 1: EEG frequency.

wave	δ	Θ	α	β	γ
Hz	1-3	4-7	8-13	13-30	30-
State	Deep Sleep	Shallow Sleep	Relax	Normal	Excite

We have normalized data of the frequency distribution power spectrum in order to eliminate the gain change effects.

$$f(x) = \frac{x - x_{min}}{x_{Max} - x_{min}} \quad \text{...............(1)}$$

Xmax: maximum of the power spectrum
Xmin: minimum of the power spectrum

A frequency which has a maximum characteristic value is the first principle. Main component scores are determined from characteristic vectors and frequency distribution power spectrum by the principal component analysis.

$$y_k = w_{k1} x_1 + w_{k2} x_2 + \cdots + w_{kn} x_n \quad \text{...(2)}$$

y_k : k-th main component score
w_k : k-th characteristic vector
x : frequency distribution power spectrum

4.3 Discrimination by Neural Networks

We have used the three layers neural networks (Fig.7) to discriminate signals which electrodes are detected when the learner feels pseudo-haptic. This neural networks selects electrodes based on main component scores.

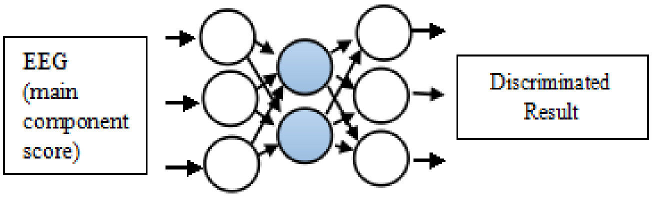


Figure 7. Neural Networks.

5. Results

We have analyzed the EEG data by normalization and FFT PCA. We have selected frequencies which has the main component scores corresponding to the cumulative contribution ratio that exceeds a prescribed value (80%). The neural networks was trained by items of these main component scores of odd number measured data. When the even number measured data "Task 1" is inputted into the neural networks, it selected electrodes AF4, CPz, F2, F7, FC6,P1,P3,P4,P5,P6,P7,P8,P03,T7,T8,TP7,TP8 are selected (Fig.8 and Table 2). When the even number measured data "Task 2" is inputted into the neural networks, it could not select electrodes.

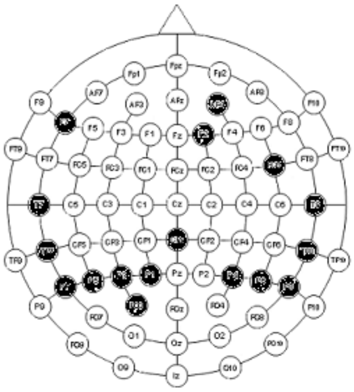


Figure 8. Important Electrodes.

Table 2: Identification rate.

Electrode	Subject1	Subject2	Subject3
AF4	61.5%	92.3%	69.2%
CPz	76.9%	69.2%	69.2%
F2	69.2%	76.9%	69.2%
F7	69.2%	69.2%	84.6%
FC6	76.9%	69.2%	69.2%
P1	84.6%	76.9%	69.2%
P3	84.6%	69.2%	69.2%
P4	84.6%	76.9%	53.8%
P5	76.9%	76.9%	69.2%
P6	69.2%	76.9%	69.2%
P7	76.9%	76.9%	61.5%
P8	61.5%	76.9%	69.2%
PO3	76.9%	76.9%	53.8%
T7	76.9%	92.3%	84.6%

T8	69.2%	61.5%	76.9%
TP7	76.9%	92.3%	61.5%
TP8	84.6%	69.2%	69.2%

6. Consideration

We have selected the important electrodes to be able to detect pseudo-haptic. These electrodes are in temporal area, temporal-posterior temporal area, posterior temporal area. The group of areas is temporal association area which processes visual perception and auditory perception to recognize information from visual cortex and auditory cortex. The parietal area data is useful to discriminate which the learner feels the pseudo-haptic. This area is related to physical sensation perception and visual perception of space. So this area recognizes what the learner watches from visual information. The pseud-haptic is an illusory perception of visual information. Therefore the brain area of visual information processing is activated when the learner feels pseudo-haptic.

7. Summary

We have studied the EEG data that the learner feels pseudo-haptic. The data have been analyzed by normalization and FFT PCA and discriminated by the neural networks. We have selected the important electrodes to detect pseudo-haptic perception. The system can recognize which the learner feels the pseudo-haptic or not from the EEG patterns. Therefore, we can evaluate the advantage of the pseudo-haptic phenomena for skill learning.

In the future work, we will try to use this pseudo-haptic for skill learning.

Acknowledgements

The research is supported by the original research project found of Wakayama University.

References

Geomagic Touch. (n.d.). Retrieved Sep. 1, 2013, from http://geomagic.com/en/products/phantom-omni/overview

Sato, M. (2002). *Development of string-based force display: Spidar*. *Proceedings of the 8th International Conference on Virtual Systems and Multi Media (VSMM 2002)*,

Crison, F., Lécuyer, A., Savary, A., Mellet-D'Huart, D., Burkhardt, J.M., and Dautin, J. (2004). *The use of haptic and pseudo-haptic feedback for the technical training of milling*. *Proceedings of the EuroHaptics Conference.*

Soga, M., Ishii, K., Nishino, T., Taki, H. (2012). *A New Method for Non-Dominant Motion Skill Learning by Using Motion Navigator*. *Proceedings of KES2012*, 953-959.

Obana, H., Ako, S., Kashu, T., Sakagami, T., Seto, Y., Miura, H., Mastuda, N., and Taki, H. (2013). *Classification of Haptic Tasks based on frequency analysis of EEG.The Papers of Technical Meeting on Innovative Industrial System, IEE Japan*, IIS-13-035. (in Japanese)

Seto, Y., Ako, S., Kashu, T., Sakagami, T., Obana, H., Miura, H., Matsuda, N., Taki, H.. (2013). *Analysis of brain state in the decision-making by using EEG. The Papers of Technical Meeting on Innovative Industrial System, IEE Japan*, IIS-13, 25-28. (in Japanese)

Seto, Y., Ako, S., Miura, H., Matsuda, N., Taki, H. (2013). *Analysis of brain state in imaging directions by using EEG, The 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC'13).*