Time-frequency Analysis of Grasp Motion and associated Motor Imagery for Event-related Desynchronization

Takaki Enomae
Master course Graduate School, Division of Engineering, Kogakuin University
Nishi-Shinjuku 1-24-2 Shinjuku Tokyo 163-8677, Japan
em14002@ns.kogakuin.ac.jp

Hisaya Tanaka
Associate Professor, Kogakuin University
Nishi-Shinjuku 1-24-2 Shinjuku Tokyo 163-8677, Japan
hisaya@cc.kogakuin.ac.jp

***Abstract*—In a brain-computer interface, using event-related desynchronization and synchronization(ERD and ERS), intuitive command input is available. Switching precision was thought to be improved by a detailed examination of the ERD μ rhythm in the time-frequency domain. In the experiment, measured electroencephalograms of motor cortex in the resting state, hand grasp motion, and hand grasp recall were analyzed. Consequently, desynchronization was observed in the band centered at 12 Hz for both the grasp motion and grasp recall.**

***Keywords*——BCI; EEG; ERD; ERS; μ rhythm**

I. Introduction

A brain-computer interface(BCI), using event-related desynchronization(ERD) and event-related synchronization(ERS), intuitive command input is available. μ rhythms are one of the band that can be used in BCI. Several factors suggest that, μ rhythms could be useful in BCI communication. μ rhythms at a frequency of approximately 8–13 Hz can be found in the primary sensory cortex and motor cortex when BCI users are not processing sensory information or producing motor output. Suppression of μ rhythms is known to correspond with movement or preparation for movement in the sensorimotor cortex opposite to the side of the body performing the motion. This suppression is referred to as ERD. ERS shows an increase in μ rhythm generated during the period and relaxation after movement. Most μ rhythms related to a BCI, ERD, and ERS are caused by motor imagery, i.e., actual movement is not necessary. Because μ rhythms are generated independently from the normal output channels of the brain that control the peripheral nerves and muscles, it is possible to use μ rhythms as a basis for BCI [1].

On the other hand, a BCI using ERD has a problem with low switch discrimination accuracy. Eight subjects participated in a study controlled BCI with a decrease in β-wave power at C3 and C4 site. However, even though all of subject showed control accuracies beyond the chance rate, none of subject shows high accuracy(max 57 %)[2]. Therefore, fast Fourier transform (FFT) analysis was used to examine the width of electroencephalogram (EEG) data and the bandwidth of the μ rhythm parameters in detail. The analysis was performed to identify a feature common to both the movement and the movement recall states. This common feature was, analyzed for each power change.

II. Analysis

First, the resting state, hand grasp motion, and hand grasp recall for motor imagery were measured at 300 ms intervals for a short-time Fourier transform analysis with an analysis width of 3000 ms. Then, the bandwidth of the μ rhythm at 8–13 Hz was added. Mean power of the mu rhythms bandwidth(8–13 Hz) were named BPMM, and maximum power of the mu rhythms bandwidth were named PSM.

III. Experiment

A. Experimental Task

Subjects alternately performed a hand grasp motion/motor imagery and resting state. First, subjects performed a grasp motion of resting state and hands and then performed the grasp motion recall of resting state and hand. The subjects remained in a rest state for 30 s at the start beginning of the experiment, and remained in the rest state for 10 s after performing the grasp motion / motor imagery task for 5 s. Each task was performed six times with both the left and right hands. EEG measurements were obtained while the tasks were being performed. Subjects were seated in a chair. The grasp motion was performed by placing one hand on the knee. The instruction to switch to grasp motion from the resting state was displayed on a notebook PC that was placed in front of the subjects(Figs. 1 and 2).

Two subjects in their twenties performed the tasks over a period of two days. The left hand tasks were measured on Day 1 and the right hand tasks were measured on Day2. Prior to participating, the subjects were given a detailed description of the experiments(Kogakuin University Research ethics review for human subjects H25–6). The experiments were conducted in a room with an environment that allowed the subjects to focus on the tasks(silent and small room).

Fig. 1 Screen presented to the subject (left:resting state, right:right hand grasp motion)

Fig. 2 Instructions presented to the subject on a laptop display

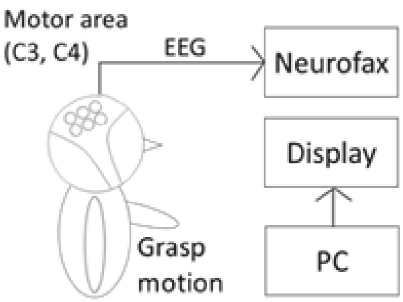

Fig. 3 Experimental environment for hand grasp motion

B. Experiment Environment

The Neurofax Nihon Kohden electroencephalograph(EEG-1100) was used. Electrode positions were set according to the International 10–20 system for C3 and C4 and were measured at a sampling frequency of 1000 Hz. A DELL DV7-6116TX notebook PC was placed in front of the subject (Fig. 3).

C. Analysis

BPMM and PSM were applied to EEG measurements. MATLAB was used for programming. Six grasp motion/motor imagery trials for right and left hands with EEG measurements were subjected to FFT analysis. Then, the BPMM and PSM at 8–13 Hz were evaluated(Fig. 3). Because suppression of μ rhythms is known to correspond with movement or preparation for movement in the sensorimotor cortex opposite to the side of the body performing the motion, the C3 was used for right hand analysis and the C4 was used for left hand analysis. From the BPMM and PSM, shows a signal that is displayed superimposed attempts each grasp motion/grasp recall, as shown in Figs. 4–7(Subject A) and Figs. 8–11(Subject B).

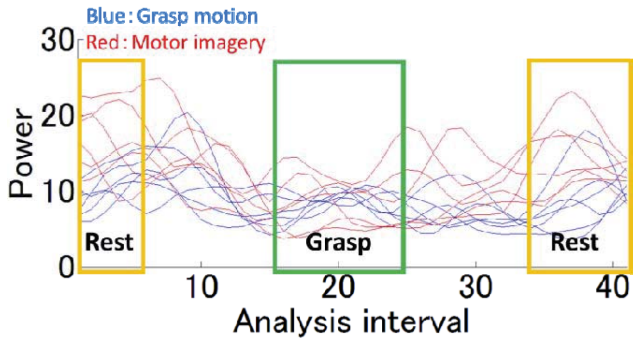

Fig. 4 Plot of resting state and grasp motion/motor imagery; BPMM, six trials, Subject A, Day 1, C3(right hand)

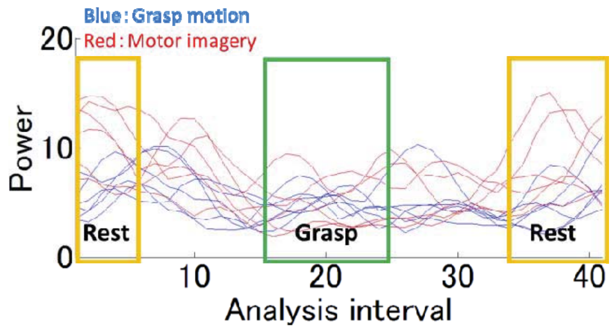

Fig. 5 Plot of resting state and grasp motion/motor imagery; PSM, six trials, Subject A, Day 1, C3(right hand)

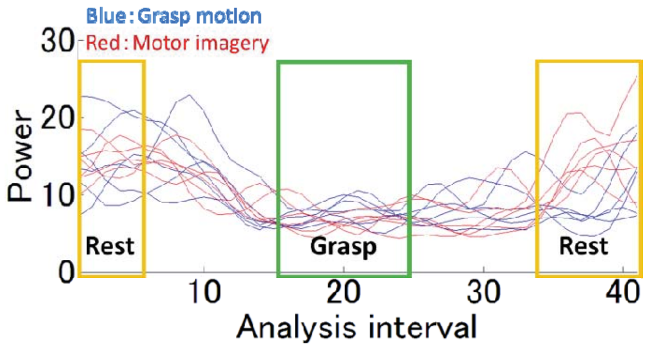

Fig.6 Plot of resting state and grasp motion/motor imagery; BPMM, six trials, Subject A, Day 1, C4(left hand)

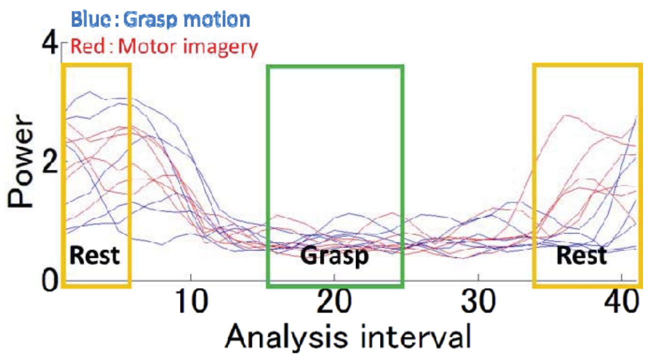

Fig. 7 Plot of resting state and grasp motion/motor imagery; PSM, six trials, Subject A, Day 1, C4(left hand)

IV. Discussion

Results of the analysis for both BPMM (Fig. 4) and PSM (Fig. 5) (Subject A, Day 1, right hand) revealed a slight decrease in power for the grasp motion. For the BPMM with the left hand (Fig. 6) for both grasp motion/movement recall, power from the resting state to the movement state appeared to have decreased (desynchronization). This was also observed for the PSM similar(Fig. 7); power decreased in the transition from resting to movement in all trials. On Day 2, power reduction

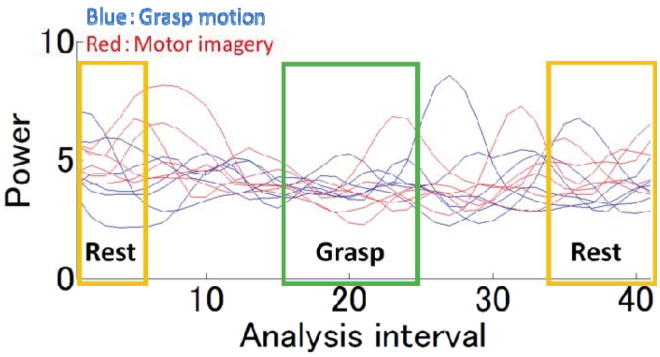

Fig. 8 Plot of resting state and grasp motion/motor imagery; BPMM, six trials, Subject B, Day 1, C3(right hand)

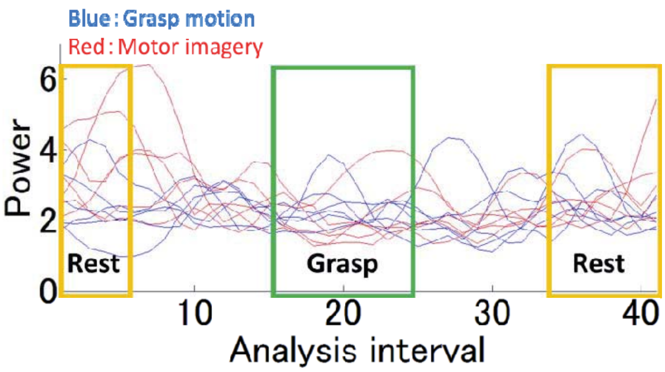

Fig. 9 Plot of resting state and grasp motion/motor imagery; PSM, six trials, Subject B, Day 1, C3(right hand)

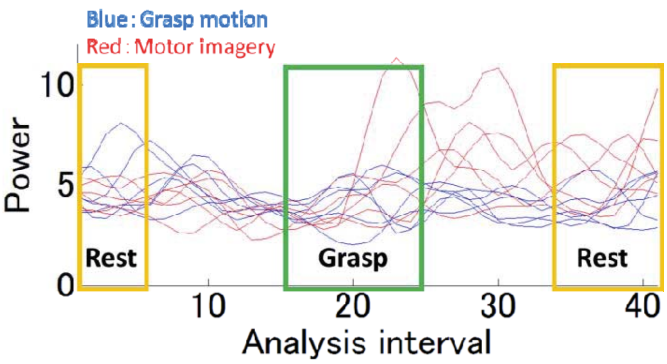

Fig.10 Plot of resting state and grasp motion/motor imagery; BPMM, six trials, Subject B, Day 1, C4(left hand)

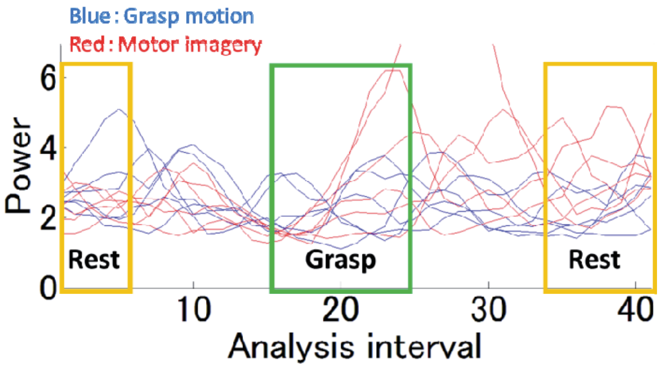

Fig. 11 Plot of resting state and grasp motion/motor imagery; PSM, six trials, Subject B, Day 1, C4(left hand)

was seen for the right hand for the BPMM in some trials. A large change in power was not observed for the left hand.

However, a decrease in power was observed for the BPMM for Subject B with tasks performed with right hand on Day 1(Fig. 8). Comparable changes were seen for the changes in PSM(Fig. 9). For the left hand, power decreases were observed for the BPMM(Fig. 10) and for some attempts with the PSM(Fig. 11). On Day 2, a small power decrease was observed during movement in the right hand for the BPMM, and power reduction was observed in the PSM trials, primarily in the grasp motion. A decrease in the early movement interval was evident in the left hand for both the BPMM and PSM.

V. Conclusions

The purpose of this research was to improve the accuracy of detecting the ERD of μ rhythm, and analyzed in a time-frequency domain. The experimental results for the BPMM and PSM indicate that similar results are found for desynchronization in the grasp motion and recall grasp motion compared with some trial and resting state.

In the future, we intend to conduct further studies to observe the characteristics of movement and movement recall. Conducting studies with other subjects should also be undertaken. In addition, we intend to detect a feature amount of time in the grasp motion. These efforts will further, the goal of improving the detection accuracy of the grasp recall status.

References

[1] BCI2000 User Tutorial: Introduction to the Mu Rhythm, http://www.bci2000.org/wiki/index.php/User_Tutorial:Introduction_to_the_Mu_Rhythm

[2] Akiyoshi Hiroyuki, Igasaki Tomohiko, Murayama Nobuki: Development of two-directional control BCI using repeated motor imagery, Technical Report of IEICE, P15-20, (2013).