BCI Mental Tasks Patterns Determination

Plamen K. Manoilov

Abstract – **Brain computer interface (BCI) is an assistive device, which translates the user's wishes in device's commands. BCI is the only possibility for completely paralysed (locked-in) people to interact with their environment. When the subject performs different mental tasks his brain issues EEG signal with different patterns. Pattern recognition approach based BCIs classify the brain activity to different mental tasks and this way makes a multichannel control. In this paper the unique characteristics finding of 5 groups mental tasks is described.**

Keywords – **BCI, EEG analysis, mental task, pattern recognition, power spectrum**

I. INTRODUCTION

Present day knowledge, about the functioning of the brain does not meet the case to guess the subject's thoughts after analyzing his EEG. BCI prototypes determine the intent of the user from a variety of different electrophysiological signals. They are translated in real time into commands that operate a computer display or other device [5]. Successful operation requires that the user encodes commands in these signals and that the BCI derives the commands from the signals. In some BCIs patterns are in a result of subject's mental load [1]. The subject performs different mental tasks, resulting in changes of the power of different frequencies in different scalp zones. The changes of the power are in large scale when the user is more concentrated. The comparison is made with the power spectrum of the subjects EEG during the performance of so called "Baseline task", task 1. The baseline task is defined like "mentally doing nothing". When the subject does nothing his alpha brain activity power has maximal values.

If the mental tasks are chosen properly, power spectrum changes for each of them are different or are issued by different spaces of the brain. This gives the possibility by the help of a classifier to bound the particular task with its power spectrum alteration (pattern). That type of devices are known as pattern recognition based BCIs. The pattern for each task is formed by the channels (electrodes) and frequencies where the most distinguishable changes occur.

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II. EXPERIMENT'S DESCRIPTION

The study continues the work on a project for creating a BCI, started in Delft University of Technology, Delft, The Netherlands in 2004, supervised by professor drs dr Leon Rothkrantz, head of Man-Machine Interaction research group, Faculty of Electrical Engineering, Mathematics and Computer Science.

During the experiments a database with 40 sessions EEG data, around 20 minutes each, recorded from two subjects (male, 25 and 30) was prepared for use together with a tool for a statistical analysis ("R", "MATLAB").

The second stage was processing the EEG from the database and finding (if possible) a specific junique characteristic for every mental task. After classifying the tasks, some of them with more clear and well-expressed characteristics could be chosen for using in BCIs control.

The brain activity of α-range (8 – 13 Hz) was studied. All EEGs were recorded without any biofeedback. In this study only five different groups tasks are examined: "Imaginary figure rotation", task 8, "Hyperventilation", task 9, "Visual presentation of ...", task 3X, "Auditive presentation of ...", task 4X, "Visual and auditive presentation of ...", task 5X. Every two-digit task includes 4 subtasks: presentation of an "yellow triangle", task X0, presentation of a "green dot", task X2, presentation of a "red cross", task X4 and presentation of "blue lines", task X6.

The figures are presented to the subject visually on the computer screen and auditively from the loudspeakers. Every task is performed multiple times per session. Tasks follow each other in a pseudo-random order to avoid a "familiarization" of the subject. The experiment schedule has planned intervals between the tasks, where the subject is allowed to blink.

As a data acquisition system "TruScan 32 EEG" was used in the experiments. It includes EEG cap with 21 silver chloride electrodes, placed according to the international "10-20" system, EEG amplifier and EEG adapter. The needed low resistance between the contact electrodes - skin was improved by the use of an electro technical gel and was controlled during the recording process. The EEG signal was filtered and sampled at 256 Hz.

FireBird DBMS was used. Matlab was used as a data processing application. The connection between them is made by ODBC protocol.

III. EEG ANALYSIS

The preliminary selection goal is to determinate the frequencies and channels where the power spectrum changes most during the mental tasks performance according to (1). The comparison is done with the power spectrum of the baseline task.

$$D(k) = P_{av}^{B}(k) - P_{av}^{R}(k)\,, \tag{1}$$

where

D - the power spectra difference.

P_{av}^{B} - the average power spectrum of the base task (task 1 or 2), calculated according to (2)

$$P_{av}^{B} = \frac{1}{M^{B}} \sum_{m=1}^{M^{B}} P^{B}(k,m) \tag{2}$$

P_{av}^{R} - average power spectrum of the running task (every task with exception of 1 and 2) according to (3)

$$P_{av}^{R} = \frac{1}{M^{R}} \sum_{m=1}^{M^{R}} P^{R}(k,m) \tag{3}$$

$P^{B}(k,m)$ and $P^{R}(k,m)$ - the power spectra of base and running tasks according to (4)

$$P(k,t) = G_{D}(k,t)G_{D}^{*}(k,t) \tag{4}$$

where

$$G_{D}(f,t) = \int_{-\infty}^{+\infty} x(t')\, g_{D}^{*}(t'-t)e^{-i.2.\pi.f.t'}dt \tag{5}$$

is Gabor transform.

The time step is a half of the segment length - $0{,}5.s_{l}$.

M^{B} and M^{R} - the numbers of the EEG segments for the base and the running task. $M^{B} \neq M^{R}$ is possible.

$M = (2l/s_{l}) - 1$, where l - is the length of the analyzed section;

As the absolute powers differs along the channels, the relative difference between the powers is calculated, (6)

$$D(k)[\%] = \frac{P_{av}^{B}(k) - P_{av}^{R}(k)}{P_{av}^{B}(k)} 100 \tag{6}$$

To assess the electrooculographic (EOG) artefacts, and more precise subjects eye blinks, influence to the chosen frequency range of 8-13 Hz, their power spectrum was examinated [2]. It was decided to cut the parts of EEG, containing blinks. Existed database is large enough. No important information might be lost. Selecting clean from EOG artefacts segments was easy to automate, because of the experiments schedule.

Duration of polluted by blink interval is user-dependent [3, 4]. For subject 1 it varies from approximately 0.8-0.2 s before and 1.9-1.5 s after the time of blink’s max amplitude. For subject 2 values are respectively 1.1-0.2 s before and 1.9-1.5 s after the blink’s max amplitude. This was used to cut properly the polluted sections.

Alpha rhythm amplitude is higher when the subject is in a physical rest state and a relative inactive mental state. It is blocked partially or completely by any mental effort.

Mu-rhythm is blocked partialy or completely by the movement or a thought about a movement.

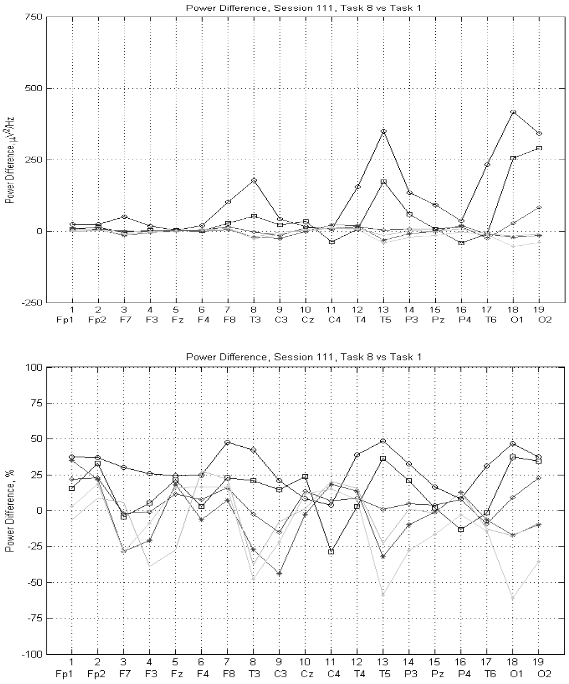

Fig. 1. Graphs of the absolute, μV 2 /Hz, and the relative, %, difference between the power spectra of baseline task, 1, and task 8. Here and everywhere in this paper:

8 Hz , 9 Hz , 10 Hz , 11 Hz , 12 Hz , 13 Hz

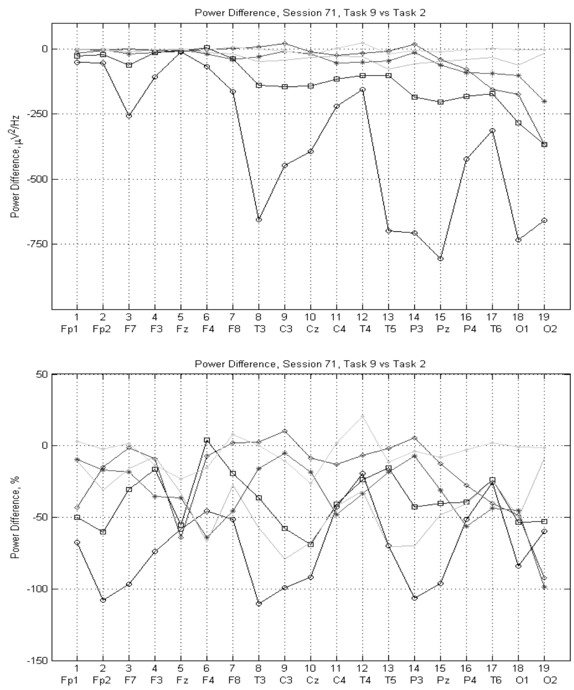

Fig. 2. Graphs of the absolute, μV 2 /Hz, and the relative, %, difference between the power spectra of baseline task, 1, and task 9

Imaginary rotation, task 8, vs. baseline task, 1

Graphs of the power difference for task 8, “Imaginary figure rotation”, are shown in Fig. 1.

From the above graph one could see that the absolute difference between the powers of the baseline task 1 and task 8 rises from the frontal to the occipital parts of the scalp. Characteristic channels with noticeable variations are P3, T4, T5, T6, O1, O2. The graph in Fig.1, below, shows however, that the relative power difference is almost equal.

Results are summarized in Table 1. The characteristics for both subjects differ. The sensitive channels for subject 2 for α-rhythm are moved to the parietal part of the scalp, μ-rhythm-appears more in the right part of the scalp.

Hyperventilation, task 9, vs. baseline task, 1

The result from the analysis of task 9 power difference, Fig. 2, is quite different. The variance between the powers of the baseline task 1 and task 9, hyperventilation, is negative. This result comes after a relative long (20-30s) ventilation of the lungs. It is impossible to meet this state in the normal human life, especially in locked-in person, with exception if it is not artificially provoked. The brain activity is clear expressed in the central and parietal parts of the scalp in the lowest frequencies of the range. Alterations above 50% could be noticed. There are differences in the spatial distribution between both subjects.

Visual presentation, tasks 3X, vs. baseline task, 1

The fourth presented objects has a similar influence on the subjects. The decreasing of the power is better expressed for tasks 30 and 34 (Visual presentation of an “yellow triangle” and a “red cross”). The presentation of a “green dot” gives the worst results-1,5 times less than the relative difference for subject 1.

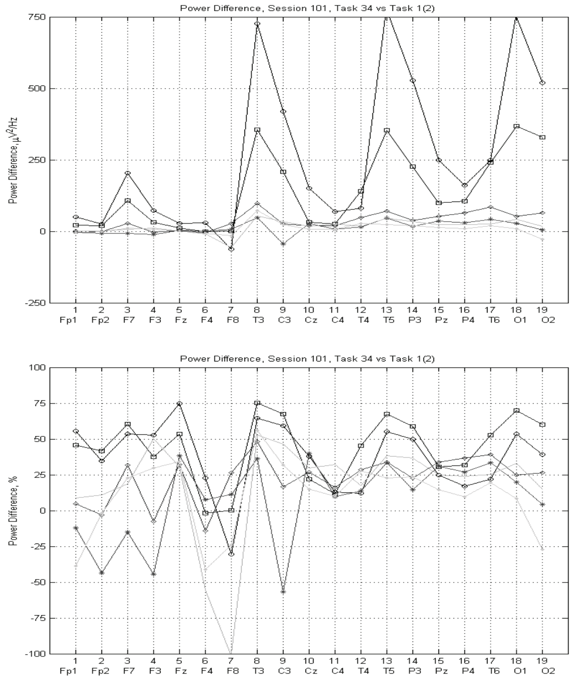

Fig. 4. Graphs of the absolute, μV^2/Hz, and the relative, %, difference between the power spectra of baseline task, 1, and task 34

Subject 2 does not show noticeable difference in brain patterns for different presented objects. Sensitive requencies are 1-2 Hz higher than for subject 1.

Audio presentation, tasks 4X, vs baseline task, 1

Graphs for task 42 are shown in Fig. 5. The audio-presentation stimulates more slight reactions in both subjects.

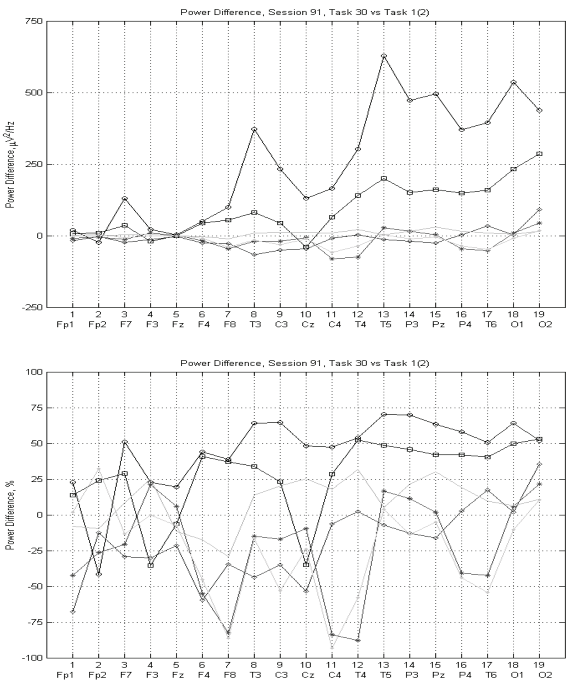

Fig. 3. Graphs of the absolute, μV^2/Hz, and the relative, %, difference between the power spectra of baseline task, 1, and task 30

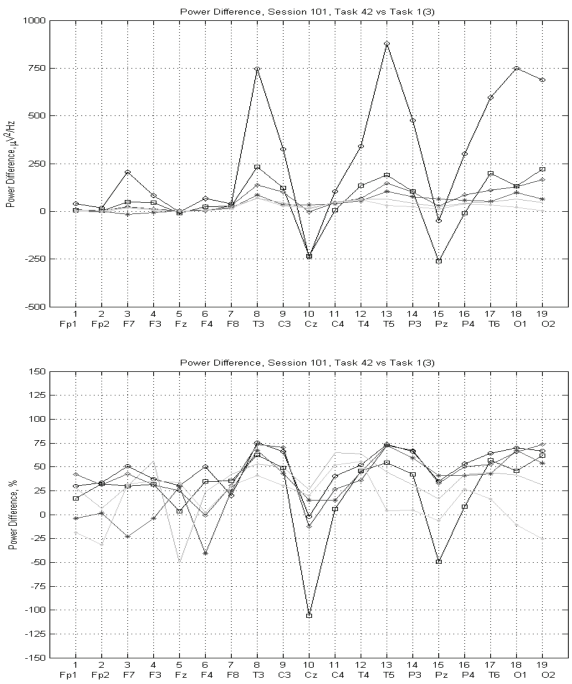

Fig. 5. Graphs of the absolute, μV^2/Hz, and the relative, %, difference between the power spectra of baseline task, 1, and task 42

It does not have different characteristics for the different presented objects. An activity in the temporal lobe is noticed in T5 and T6 for subject 1 and in T6 for subject 2.

Audio-visual presentation, tasks 5X, vs baseline task, 1

The audio-visual presentation combines visual- and audio-presentations features. An activity in the temporal and the occipital part of the scalp is noticed.

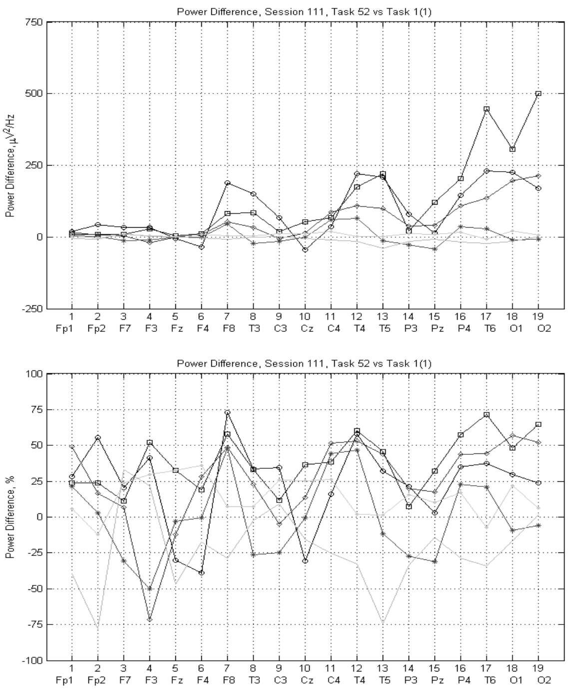

Fig. 6. Graphs of the absolute, $\mu V^2/Hz$, and the relative, %, difference between the power spectra of baseline task, 1, and task 52

IV. Conclusions

The following conclusions could be made:

1. Unlike the other tasks, task 8, "Imaginary figure rotation", alters μ-rhythm and α- rhythm in frontal placed electrodes. It has an unique characteristic. User should use to achieve this state for a short time.
2. In comparison to the other tasks, the "Hyperventilation", task 9, is not an ordinary one. To achieve the hyperventilation state the subject have to bread deeply a long time. The task is not useful for a trivial control. The well expressed and quite different characteristics of task 9 could be used to switch on/off the BCI. As this state does not exist in the normal life, no errors are possible.
3. Power spectra changes in a result of mental tasks performance are individual for each subject. Control of proper frequencies for every user should be foreseen in the BCI.
4. The presentation of different geometrical figures and colors does not result in different patterns, but has more or less marked patterns for each subject. Signal colors, which tease the subject, give more clear expressed patterns. Selection of the proper figure and color for every subject is necessary to achieve the best results.
5. From the three group of tasks 3X, 4X, 5X, the "Visual presentation of…" is the most useful for using in BCI. The characteristics could be achieved by self-concentration. No outside assistance is needed.

On the next stage of the work the stability of the characteristics during the performance of each mental task will be studied. After the time interval of the best expressed pattern is determined the final mental task selection could be done.

TABLE I
MENTAL TASKS CHARACTERISTICS SUMMARY

Task	Subj.	Rhythm-Chann:Frequency[Hz]
Imaginary figure rotation, task 8	1	α – F8, P3, T4, T5, T6, O1, O2 : 8, 9
	1	μ – C3, P3 : 9
	2	α – F8, P3, Pz, P4, T6 : 9-11
	2	μ – C3, Cz, C4, P3, P4 : 9-11
Hyperventilation, task 9	1	α – Fp2, C3, Cz, P3, Pz, P4, T3 : 8
	2	α – Fp1, F3, Fz, F4, C3, Cz, P3, Pz, P4, T6 : 8, 9, 10
Visual presentation, tasks 30, 32, 34, 36	1	α – P3, T5, T6, O1, O2 : 8, 9
	2	α – O1, O2 : 9, 10
Audio presentation, tasks 40, 42, 44, 46	1	α – T5, T6 : 8 -11
	2	α – T6 : 9 – 11
Audio-visual presentation, tasks 50, 52, 54, 56	1	α – O1, O2, T4, T6 : 8-11
	2	α – O1, O2, T4, T6 : 8-13

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