

Adaptive Interactive Learning for Training BCI Systems

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Introduction: A usual set of instructions for a test subject participating in an imagery-based BCI experiment would ask to think *left* when the arrow on the screen points to the left and to think *right* when the arrow is pointing to the right. A very common question a BCI experimenter could hear from a test subject at this point is “How should I think?” Indeed the request to think *left* is quite ambiguous. Should the test subject imagine an arrow in his mind, concentrate on the abstract notion of “left”, engage in imagery motor activity or just think about an unrelated concept? The answer to this question is user-specific and thus it is required to run a separate experiment to find a mental action the user should evoke when cued with the “left” stimulus. In this work, we improve the training process of an imagery-based BCI system by introducing an interactive component, which facilitates a “dialog” between the underlying learning algorithm and the test subject. The method described in this work employs self-organizing map (SOM) [1] to project brain signal representation from the high-dimensional feature space into 2D space, allowing the test subject to visually explore the space of his mental states and observe the relative effect of the mental actions he evokes. Via the interaction with the system user can search for the mental actions he can evoke consistently and which are distinguishable by the classification algorithm. Once a set of such mental actions is found, it can be used in a real-time BCI system.

Materials, Methods and Results: In our approach we rely on an extension to SOM, which we refer to as *Predictive SOM*. Predictive SOM is built in the same way as the usual SOM, but each unit u of the map has an additional vector $\mathbf{p}(u) \in \mathbb{R}^a$ where a is the number of stimuli. This vector holds stimulus probability distribution for the unit u : it shows what is the probability that a signal \mathbf{x} , which was classified into unit u , has been produced in response to the stimulus a . This mechanism allows SOM to act as an online classifier, which outputs predictions for each new data sample and then updates the model (thus *adaptive*). An important property of SOM is that it attempts to preserve topology of the data: samples (EEG signals in our case) which were close in the original high-dimensional Fourier space will also be close in the 2D space after the projection to the map. The projected signal is shown to the user on the screen (this *interactive*) and reflects in real time how user’s mental actions affect the internal signal representations the system has.

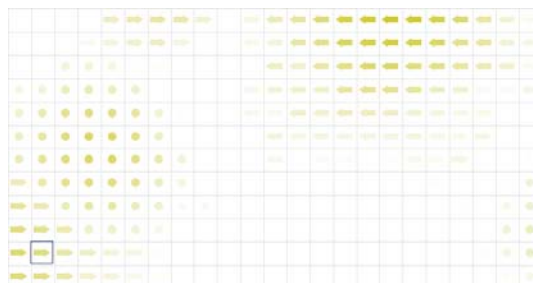


Figure 1. 2D visualization of the signal space instead of the usual stimulus screen. The map changes in real time as new brain signals arrive. Icons represent mental actions associated with the units on the grid. Highlighted cell shows to the user where the signal he is currently producing ends up on the map of internal representations.

The prototype system was tested using Emotiv EPOC. We are currently in the stage of conducting experiments with a proper EEG device (BioSemi ActiveTwo) and larger number of test subjects. The proposed method is compared to the baseline with the classical way of presenting the stimulus with real-time feedback. The results on the prototype system with 5 test subjects show an increase of accuracy by 0.07 on a mental activity task with 3 classes (left, neutral, right).

Discussion: Although the current work focuses on a particular type of BCI systems, the concept can be applied to a wider range of human-computer interaction tasks. In this work we show how the method is used to find the set of mental actions that would be suitable for a BCI system, however one can imagine employing the same investigative paradigm to explore the mental state space of a test subject in less restricted regime, where there is no fixed goal. This might turn out to be useful in psychological studies and also could be interesting to the general audience as it provides a peak into relative organization of their mental state space.

Significance: The article proposes a novel way of interaction between the learning system and BCI user and demonstrates the advantages of the proposed approach.

References

- [1] Kohonen, T. (1990). The self-organizing map. Proceedings of the IEEE, 78(9), 1464-1480.