Hybrid EEG and fMRI platform for multi-modal neurofeedback

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Introduction

Neurofeedback (NF) can be defined as the self-regulated change of a particular brain activity that is reflected in the change of one or a combination of neural signals such as EEG or fMRI. There exist a variety of unimodal (i.e. EEG) NF researches [1, 2], but due to the technical difficulties [4-6] very few use multimodal brain signals [3].
In this abstract we describe a hybrid EEG-fMRI platform that we have developed for our NF experiments, including its hardware/software components and their roles.

Methods

Our platform is based on the integration and the synchronization of an EEG and an fMRI acquisition subsystem (Figure 1).

The EEG signals are acquired with a ***64 channel MR-compatible subsystem*** from Brain Products, that provides:

1. MRI phase synchronization for the MR gradient artifact removal
2. an ECG channel for ballistocardiogram artifact removal

Filtering is done in real-time using the vendor's software (*RecView*).

The EEG signals are send to the ***EEG object*** via TCP/IP. This object can pre-process, filter, extract features, train NF models and estimate EEG-NF in real-time. The results are sent to the *Joint NF*.

The MR imaging is performed on a 3T Verio Siemens scanner (VB17) with a 12-ch head coil. High resolution structural 3D T1 is acquired, followed by task-related fMRI acquisitions.

The fMRI data is sent in real-time to the ***fMRI object*** via TCP/IP. This *object* can pre-process volumes (i.e. realignment, slice-time correction, smoothing), extract regions of interest and features, train NF models, and estimate fMRI-NF. Similarly with EEG, the results are sent to the *Joint NF*.

The ***Joint NF*** does the fusion of the EEG and fMRI NFs, and then sends the results to *Visualize*.

Visualize controls the display that communicates with the subject. It has a collection of visual objects for explaining the NF tasks and for animating the NF representation (Figure 2).

The ***NF Control object*** contains the experiment protocol (types of tasks, duration, repetition, etc.). It starts/stops the experiment, controls all the other objects' behavior throughout the experiments, and stores the data.

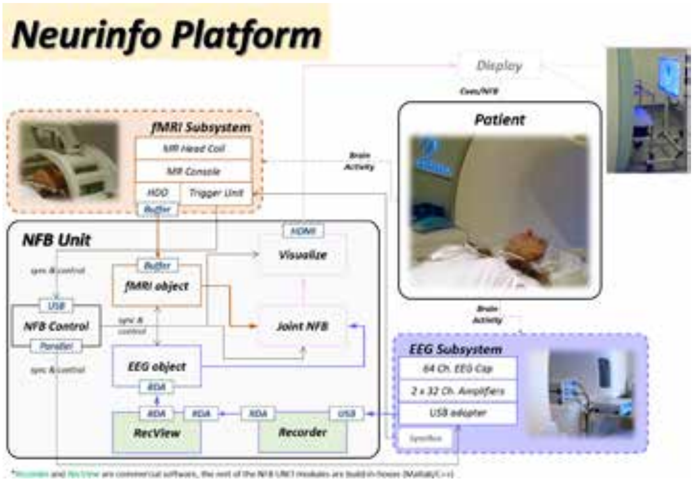

Figure 1. Diagram of the developed hybrid EEG-fMRI neurofeedback system

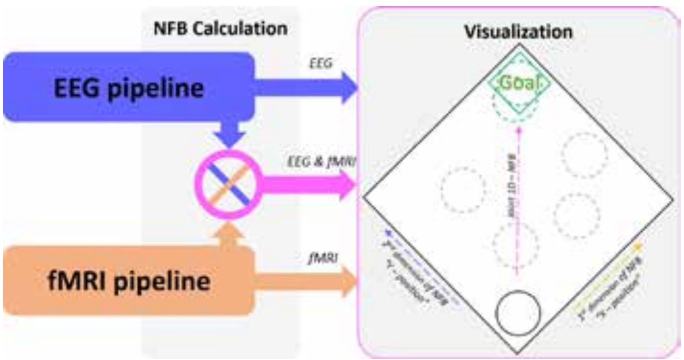

Figure 2. NFB task visualization example.

Results

Our platform showed very good real-time performance when tested with various pre-processing, filtering, and NF estimation and visualization methods.

The entire fMRI processing from acquisition to NF estimation in all scenarios takes less than 200ms, well below the TR of regular EPI sequences (2s). The same processing for EEG, is done at 2ms (~50Hz).

Various NF tasks scenarios for regulating the measured brain activity were tested with subjects. In particular, the platform was used for a NF study on 10 subjects with over 50 sessions using three NF protocols based on motor imagery related brain activity.

The NF task was to put the white circle into the goal box (Figure 2). The brain activity (EEG & fMRI) was used to estimate the NF and then translated into 2D motion of the circle toward the goal.

Figure 3. Snapshot of a NFB experiment

Conclusions

The platform presented here proved to be reliable and efficient during hybrid EEG-fMRI NF experiments. Its modular architecture is easily adaptable to different experimental environments, and offers high efficiency for optimal real-time NF applications.

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