Signal Extraction for Brain-Computer Interface

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Abstract

Understanding the functional processes of the brain is still a new and difficult task. Functional Magnetic Resonance Imaging (fMRI) is a relatively new tool with the purpose of mapping the sensor, motor and cognitive tasks to specific regions in the brain. The underlying mechanics of this technique is in the regulation of the blood flow as an excess of oxygen is supplied to active neurones causing an increase in oxygenated blood surrounding the tissue of the active brain region. The difference between oxygenation can be measured using a MR scanner due to the different magnetic properties of oxygenated and deoxygenated blood. This effect is referred to as the Blood Oxygenation Level Dependent signal (BOLD). A more detailed description of the BOLD signal and its usage in MR scanners can be found in [3].

We present an approach based on Kernel Canonical Correlation Analysis (KCCA) to automatically measure the active regions of the brain using fMRI scans and time frequency of the task [5]. Friman et. al [2] have shown that Canonical Correlation Analysis (CCA) can give a more accurate result than currently established techniques such as *t*-test and *F*-test (the reader is referred to [2] for more details). In [2] a sliding window approach is undertaken where the fMRI scan is divided into subsections and activity is measured for each of the subsections. We show that KCCA can not only find the active regions without needing to divide the fMRI scan into subsections, but can also find the active regions on all slices at the same time. As KCCA measures activity with regard to every pixel on the fMRI scan (representing every region of the brain) a higher accuracy in activity measure is obtained. We show that negative correlation may occur as regions of the brain may be active but not to the task at hand.

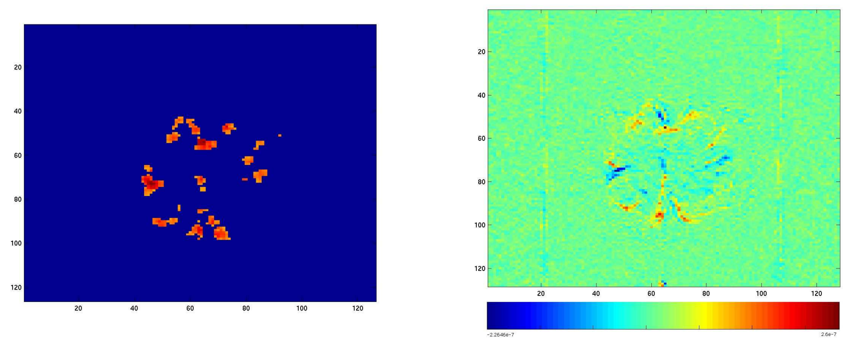

Figure 1: Images of the Mental calculation task. Left image: CCA correlation mask. Right Image: KCCA weighted image (Weight scale from -2.2646e-7 to 2.6e-7)

In Figures 1 and 2 we present a comparison between KCCA (right image) to the baseline

CCA approach (left image). The presented results in Figure 1 are of a mental calculation task where the volunteer was required to add two numbers that were projected onto the wall of the scanner room on an interval of $T = 15$ i.e. 15 frames performing the task, 15 frames resting. Resulting with a total of 180 frames per slice. The presented results in Figure 2 are of a finger flexing task where the volunteer was required to flex his right index finger on an interval of $T = 10$ i.e. 10 frames performing the task, 10 frames resting. Resulting with a total of 200 frames per slice. In Figure 1 and 2 we can view the results for the 12'th slice. The left image is the CCA correlation mask obtain with a threshold, which was obtained by a heuristic approach. The right image is the KCCA reproduction of the original image with associated weights to each pixel. Both figures presented expected active regions. We observe that not only the activation (deep red) is more refined in the KCCA weighted image, but that there are regions which are found active in CCA while in KCCA are found active with a negative weight (deep blue) (as in Figure 1) or not active at all (in both figures). We speculate that the active regions with the negative weight as found by KCCA are active regions but not in correlation to the task [4].

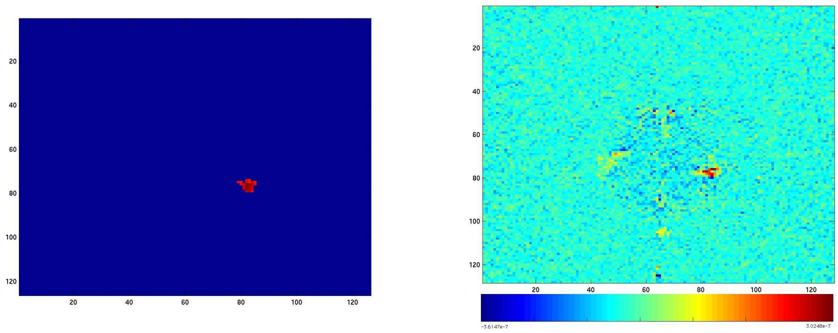

Figure 2: Finger flexing. Left image: CCA correlation mask. Right image: KCCA weighed image (weight scale from -3.6147e-7 to 3.0248e-7)

We are able to apply the extracted KCCA features on an unknown set of fMRI scans, which is of the same task as the training fMRI scans, and be able to statistically reconstruct the unknown test-set time frequency. Active brain regions associated with the task would also be automatically extracted. We further propose this method for a signal extraction technique to be used as a brain-computer interface. We hypothesis that if able to extract both the active brain regions and the time frequency associated with the task we could translate it via a brain-computer interface into an actual task, such as moving and click of the mouse correlated to the region of the brain which is responsible for finger flexing. A further interesting avenue would be to observe the performs of applying our KCCA approach to other techniques of brain analysis and also more complex tasks. As we speculate that KCCA would be able to handle a multiple task fMRI scenario where baseline methods require scans of individual tasks.

References

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