Deconvolution of component map time courses for task related activation discovery

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Problem. Many behavioral studies of brain activity seek to find task related activation given a set of observations representing a mixture set of signals. Independent components analysis (ICA) is a statistical method for recovering the independent sources in a set of mixed signals. With respect to medical imaging, it has been used to discover spatially independent component maps as well as the mixing matrix representing the time course activation for the different component maps. Previous work applying ICA to cranial functional magnetic resonance imaging (fMRI) datasets measured correlation between component map time course activation and a task reference function [2]. In fact, many behavioral studies use several behavioral tasks that activate cognitive areas in complex interactions not easily represented in a reference function. Further, many studies involve a relatively large number of trials to capture a sufficient activation effect, requiring random task assignment to particular trials. The problem we address is detecting task related signals when the experimental design does not lend itself to generating a reference function.

Method. We want to order component maps according to task relevance by grouping observations by trial tasks and applying components analysis to task groups $X = AS$. The generated activation time courses of component maps (the columns of A) are a convolution of the *between trial* activation function ($g(x)$) and a function of component map activation ($f(x)$). Essentially, grouping trial observations by trial tasks convolves the component map activation function with a periodic square wave function. The goal is recovery of the Fourier transform of the activation time course function ($\Im(f(x))$) using the convolution theorem: $\Im(f * g) = \Im(f) \cdot \Im(g)$.

We estimate the between trial activation function in frequency space using $sinc$ functions whose parameters are derived from the experimental design $g'(x)$ (handling discontinuities where $\sin() = 0$ and $\mathrm{sinc}(g(x))^{-1}$ indicates the multiplicative inverse). Using the convolution theorem, we factor the estimated function g' in frequency space to generate an activation function estimate: $\Im(f * g) \cdot \mathrm{sinc}(g')^{-1} = \Im(f) \cdot \Im(g) \cdot \mathrm{sinc}(g')^{-1}$. We order component maps by amplitude in the critical frequency range $\{c - \delta \ldots c + \delta\}$ and note activation in the region of interest (ROI) of component maps.

Experiments. We apply the method to component map time courses generated using FastICA on datasets of a variety of experimental designs. The first dataset contains single subject pilot data of auditory stimuli using an experimental design similar to that used in previous work [2]. The second dataset represents single subject performance of a motor study using functional imaging [1]. The third dataset is data collected for a study on spatial working memory [3]. We order time course activations according to task relevance for each of the datasets. We show initial results of rendered component map activation in areas salient to the behavioral task.

In the first dataset, high ranking task relevant component maps show activation in the task related areas found in previous analysis of the dataset. In the second dataset, task related activation is harder to find in this formulation because the experimental design does not time lock event onset. The third dataset is perhaps the most interesting when compared to previous analysis. Highest ranking task related components indicate activation in the frontal cortex area, the ROI of the original study. However, the component map activations are diffuse. Previous analysis indicated saccade related activation in the ROI, corroborating a hypothesis that the superior frontal cortex does not play a role in spatial memory manipulation tasks.

This work develops a method for ranking task relevance of ICA generated component maps. Preliminary results show some promise for the method. In general, where a reference function is not obtainable, we appeal to other properties present in task related signals. An important application of discovery of task related components is generating *task* time course of activation using principal subspace of highly task related components.

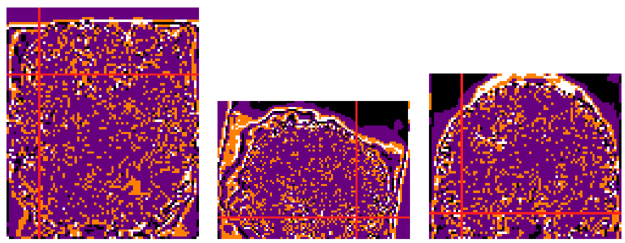

Figure 1: ICA generated component map (unfiltered) indicating activation in the general area of the primary auditory cortex.

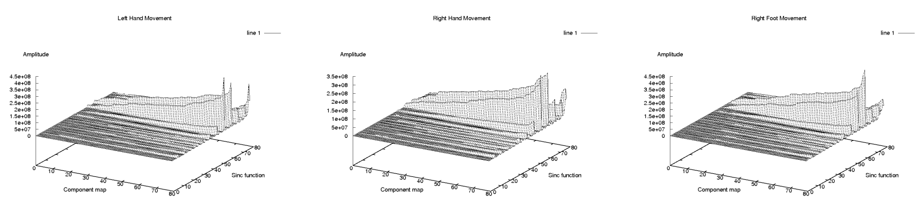

Figure 2: Amplitude surfaces for experiment tasks of function imaging motor study.

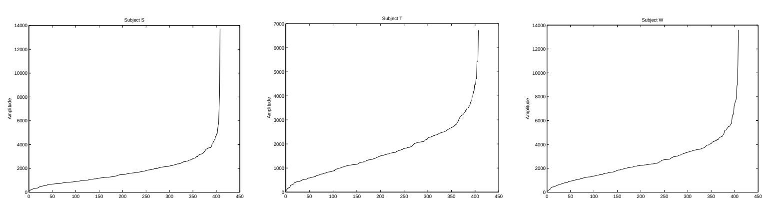

Figure 3: Amplitude of ordered components ($c = 17$) for three subjects in manipulate memory experiment task [3].

References

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