Spatio-temporal methods in the analysis of fMRI data in neuroscience

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This thesis considers methods used for analyzing functional Magnetic Resonance Imaging (fMRI) data of the brain. fMRI is a brain imaging technique which, over time, records changes in blood oxygenation level that can be associated with underlying neural activity. However, fMRI images are typically very noisy and extracting useful information from them calls for a variety of methods of analysis.

There are two main parts in the thesis. The first part centers around an investigation into how justified and robust is the technique Independent Component Analysis (ICA) which is currently being used in the analysis of fMRI data. In the second part, a criterion is developed on which a new method for analyzing fMRI data can be based.

A typical assumption made in analyzing fMRI data is that the total brain activity at any given time is a linear combination of different "components" of activity. ICA methods further assume that these components are spatially (statistically) independent, and it is this assumption that allows such components to be identified out of the total brain activity. We argue that independence is not a very realistic assumption for the components in the brain from a biological viewpoint since it corresponds to a very precise overlap condition on the spatial parts (called "spatial maps") of these components.

In order to test this assertion, we investigated how two popular ICA algorithms, Infomax and FastICA, performed on simple simulations of fMRI data. An example of some of the results of these tests are shown in the figure. The top two squares are two independent spatial maps which we simulated, the squares in the next row are mixtures of these two components. These mixtures were fed into each of the two ICA algorithms being considered and the results found by the algorithms are also displayed (in this case, neither algorithm succeeded in finding the correct components even though the components were constructed so as to be spatially independent). From running experiments such as these, we found that both ICA algorithms can fail to correctly identify components even when they are constructed so as to be spatially independent, but can correctly identify components that are constructed so as to be spatially dependent.

The new approach for fMRI data analysis which is set up in the second part of the thesis encourages the spatial parts of the components identified from the fMRI data to be both *localized*, a property neuroscientists believe is likely, and *smooth*, a property that is clearly biologically reasonable since fMRI measures changes in blood oxygenation which would vary smoothly across the brain. This is done via a variational problem which incorporates a weighted l^1 norm on expansion coefficients with respect to suitable wavelet bases.

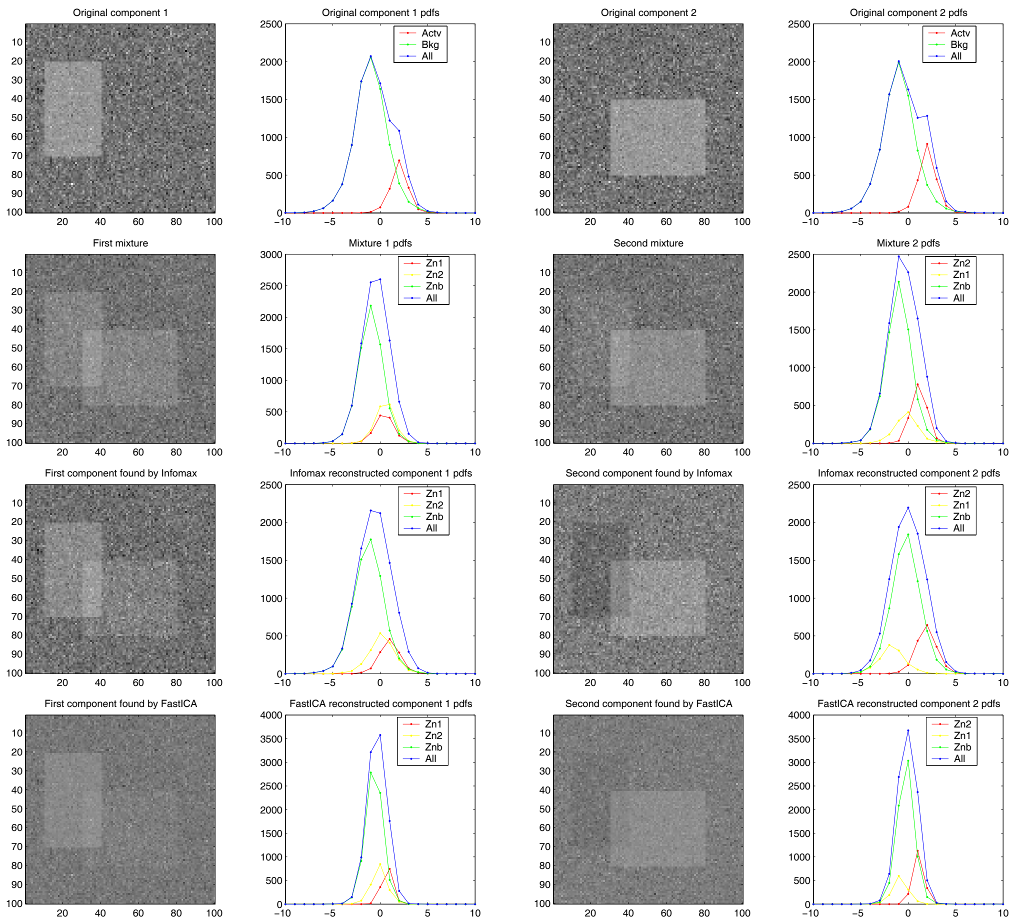

Figure 1: Neither Infomax nor FastICA successfully separates these independent components.