



Incremental Cluster-Wise Regression Analysis of Functional Brain Stimulation-Activation Data

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Introduction

What do humans visually sense in natural environments and how do they arrive at this sensation? To answer this question, we subject humans to visual stimulation in the form of natural video scenes while their brain activity is measured via whole-brain modalities such as M/EEG and fMRI. Our aim is to identify visual scene features at varying levels of detail (e.g. color, depth, texture, motion, objects) that can be reliably mapped to human brain function. To this end, we develop and apply advanced computer vision, neuro-image analysis, machine learning and data mining methods. Here, we describe the application of an incremental cluster-wise regression analyses method within the 2006 Pittsburgh Brain Activity Interpretation Competition [5].

Data

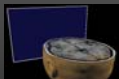
The 2006 PBAIC involves analysis of fMRI data of 3 subjects who watched three 20-minute movie segments. The subjects completed extensive ratings of multiple features (e.g., attention, faces, music, kitchen) in three categories, representing what they perceived during the fMRI scan. The fMRI data are provided to contestants along with the feature ratings for Movie1 and Movie2. For Movie3, fMRI data are provided but no feature ratings or other content information. The goal of the competition is to predict the experience (feature ratings) of the 3 subjects watching Movie3 purely based their fMRI data.

Results

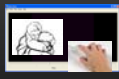
For the Base category, highest cross-correlation scores ranged between -0.13 ("Tools") and 0.40 ("BodyParts"), with an average of 0.11. In the category Actor, we obtained correlations of up to 0.65 ("Jill"), with an average of 0.46 by far the best predictions among the 40 participants in the 2006 PBAIC. Likely explanations for the discrepancy between the results in Base and Actor category are: (i) parameters were set for superficial exploration of functional spaces for Base category versus intensive exploration for Actor category (ii) blanks ("movie off" parts) were included in the analysis, adversely impacting continuously present (Base) features such as "Faces" and "Motion", (ii) low agreement in subject feature ratings for Base versus high agreement in Actor category.

Learning

Image courtesy: Pittsburgh Brain Activity Interpretation Competition

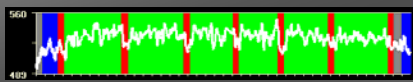


Activation (voxel signal from subject fMRI scan)



Stimulation (feature signal from subject rating)

Predicting

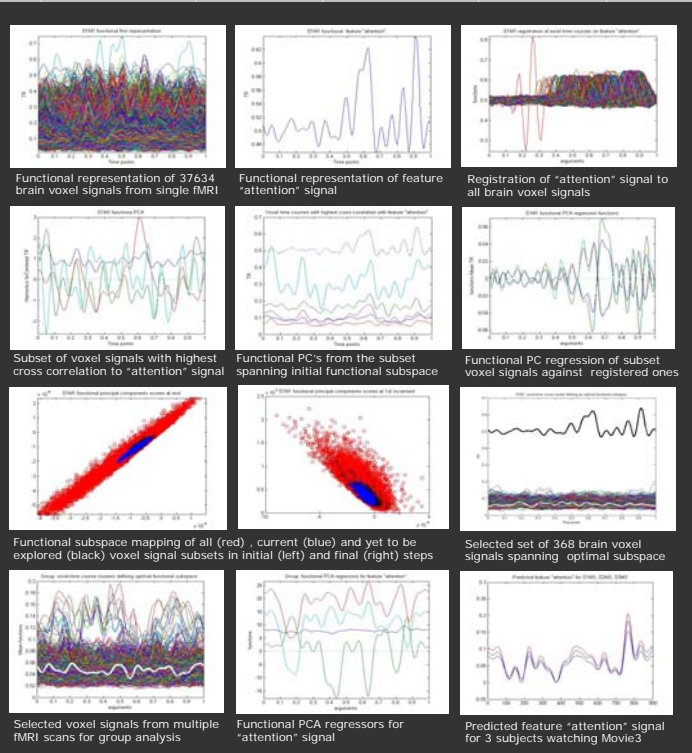


Use method to predict feature signal

Method

Well-established brain activity analysis methods such as SPM [1] and FSL [4] are broadly used for brain function studies involving well-defined stimulations. Other widely-known methods such as PCA and ICA are useful for brain function studies with undefined stimulations. Our brain activity analysis method also handles ill-defined stimulations, occurring for example when passively viewing natural movies. The method differs from existing ones in that it (i) represents both stimulation and activation signals as continuous multivariate data, allowing the use of advanced nonparametric functional data analysis [3] and (ii) adopts a "search-model-fit" strategy [2], allowing to discover local recurring similarities between activation and stimulation signals. The method also accounts for variation in Haemodynamics across brain areas and among subjects.

In the 2006 PBAIC, we applied our method to predict feature ratings in Base and Actor categories for Movie3 (see illustration for a schematic explanation). We represented both voxel and feature signals as functional data. In the learning phase, a population-based incremental learning algorithm was used to explore systematic components in each subject fMRI scan, using feature signals to steer the exploration. This resulted in a set of potentially relevant voxel signals for each feature and each fMRI scan. In the subsequent group analysis, each set was explored once again for systematic components to identify optimal functional subspaces across subjects. In the predicting phase, these subspaces, represented by a spatiotemporal regression model per feature, were used to predict feature ratings of the 3 subjects for Movie3.



Conclusion

We propose a brain activation-stimulation data analysis method that can handle a variety of stimulation types. In case of well-defined stimulation, the method reduces to a standard model-and-fit approach. For ill-defined stimulation, the method searches for systematic components in the brain activation related to the stimulation. If the stimulation is undefined the method separates systematic components from noise. The method can be used to identify brain activity given stimulation data, or to predict stimulation data given brain activation data.

References

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