

Chapter 11

Review of fMRI Data Analysis: A Special Focus on Classification

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ABSTRACT

Classification of brain states obtained through functional magnetic resonance imaging (fMRI) poses a serious challenges for neuroimaging community to uncover discriminating patterns of brain state activity that define independent thought processes. This challenge came into existence because of the large number of voxels in a typical fMRI scan, the classifier is presented with a massive feature set coupled with a relatively small training samples. One of the most popular research topics in last few years is the application of machine learning algorithms for mental states classification, decoding brain activation, and finding the variable of interest from fMRI data. In classification scenario, different algorithms have different biases, in the sequel performances differs across datasets, and for a particular dataset the accuracy varies from classifier to classifier. To overcome the limitations of individual techniques, hybridization or fusion of these machine learning techniques emerged in recent years which have shown promising result and open up new direction of research. This paper reviews the machine learning techniques ranging from individual classifiers, ensemble, and hybrid techniques used in cognitive classification with a well balance treatment of their applications, performance, and limitations. It also discusses many open research challenges for further research.

1. INTRODUCTION

The complexity of the brain has been the primary research of many studies and experiment since remote times. Although the development of advance techniques improve our understanding about brain, still far from being completely understood. The cognitive neuroscience is evolving with the new neuroimaging techniques combined with experimental techniques which provides us images of the structure or function of the brain. The magnetic resonance imaging (MRI) uses a powerful magnetic field and radio waves to

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produce highly detailed images of the human body which shows injury, diseases process or abnormal condition (McGowan, 2008). fMRI technology used to detect the localized changes in blood flow and blood oxygenation which occur in the brain in response to neural activity (Ogawa et al., 1990; Savoy, 1999). The fMRI has evolved as one of the most successful tools in the investigation of cognitive function. The objective of fMRI data analysis is to extract the functional correlates from the given image and identifies brain regions of interest. The fMRI data analysis either uses single-voxel approach which creates activation maps by testing each voxel separately for correlation with the experimental paradigm or pre-define a region of interest (ROI) based on either anatomical or functional data (Heller et al., 2006). The new method developed based on regional homogeneity (ReHo) uses Kendall's coefficient concordance (KCC) to measure the similarity of the time series of a given voxel to those of its neighbors in a voxel-wise way for fMRI data analysis (Zang et al., 2004). The classification techniques can identify many types of activation patterns within or shared across subjects (Etzet et al., 2009). Among the analytic tool used for fMRI data, the multi-voxel pattern analysis (MVPA) can detect information which is inaccessible to traditional univariate approaches (Coutanche et al., 2012). Due to its multivariate nature, MVPA approach is sensitive to differences in the voxel activation patterns among different cognitive states (Yang et al., 2012).

As a part of this review, this paper studies the challenges involved in the classification task and different machine learning approaches performing the classification activities and the requirement of ensemble and hybrid classification. In particular, the various classification approaches for cognitive states discrimination developed under the umbrella of machine learning techniques have been reviewed.

The rest of the paper is set out as follows. In Section 2, the overview of machine learning and challenges in cognitive classification has been discussed. Some popular machine learning approaches used for cognitive classification is discussed in Section 3. The ensemble techniques are reviewed in Section 4. Hybrid techniques and their applications are reviewed in Section 5. The classification performance and comparison among different hybrid techniques are discussed in Section 6. Future perspectives and conclusions are derived in Sections 7 and 8, respectively.

2. MACHINE LEARNING AND CHALLENGES IN fMRI

This section is a conglomeration of two subsections 2.1 and 2.2 for briefing machine learning and discusses the challenges of fMRI respectively.

2.1. Briefing of Machine Learning

Machine learning is programming computers to learn for optimizing a performance criterion using example data or past experience. It uses the statistics theory in building mathematical models, as the core task is making inference from a sample (Alpaydin, 2004). The most vital question in the context of machine learning is how to make machines able to learn where learning considered as inductive inference. There are three categories of learning:

1. Unsupervised learning,
2. Supervised learning, and
3. Reinforcement learning

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