Classifying Multiple-Subject fMRI Data Using the Hierarchical Gaussian Naïve Bayes Classifier

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Introduction

In a typical fMRI study, data from multiple subjects are usually available, increasing the number of potential training examples for a classifier, so that it can potentially make better predictions compared to one trained separately for each subject. Nevertheless, even though the same task presumably gives rise to similar fMRI activations across subjects, there are also variations specific to each particular subject. I present an extension of the Gaussian Naïve Bayes (GNB) classifier that can account for subject-specific variations.

Method

In a GNB classifier, for each feature in subject *s*, each data instance *i* is distributed class-conditionally as

$$y_{si} \sim N(\theta_s, \sigma^2)$$

independent of the other features. I extend this by assuming that for the same feature in all the subjects, the mean θ_s is distributed as

$$\theta_s \sim N(\mu,\tau^2)$$

Given the model, a new estimation procedure for the parameters can be derived, using the parametric empirical Bayes methodology, leading to the *hierarchical GNB* classifier.

Datasets

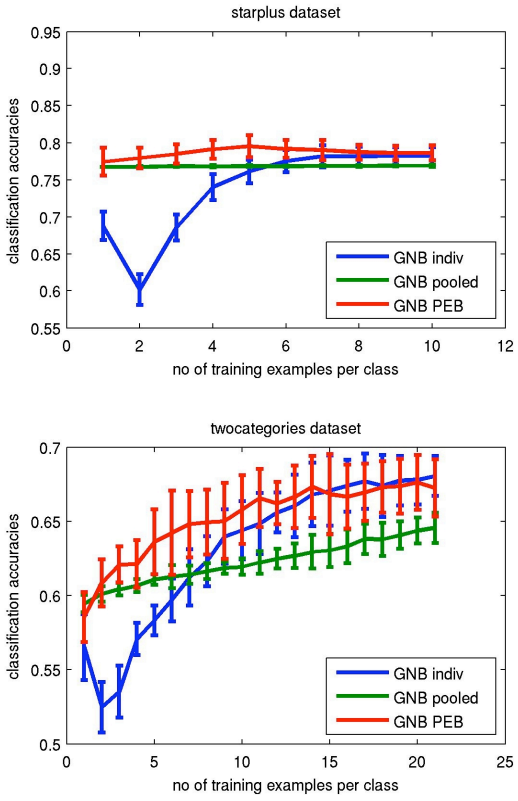
I tested the method on two datasets. In the starplus dataset, in each trial, each subject looked at a pair of sentence and picture and had to decide whether the sentence described the picture. The first stimulus was presented for 4 seconds, followed by an 4-second fixation period, and the second stimulus was presented for 4 seconds or until the subject made the decision. The classification task is to decide the category of the viewed first stimulus, either sentence or picture. fMRI images were captured every 500ms, and the time points of the average of the voxels in region around the calcarine sulcus become the features of the classifier. Data from 13 subjects were used.

The twocategories dataset comes from a study where each subject viewed words belonging to the categories tools and dwellings and had to think about the properties of the corresponding objects. Each

word was presented for 3 seconds, with an ISI of 7-8 seconds. The classification task is to classify the category of a presented word. fMRI images were captured every 1000ms, and the averages of time points 5 to 8 for 300 voxels with the highest class-separability scores become the features of the classifier. Data from 6 subjects were used.

Results

In the experiments, I iterated over the subjects, choosing the current one as the test subject. Two-fold cross-validation was performed on the test subject's data. Three classifiers were tested: GNB trained on the test subject's data only (GNB-indiv), GNB trained on all of the subjects' data (GNB-pooled), and the hierarchical GNB (GNB-PEB). Figures 1 and 2 show the accuracies with standard errors of the test subjects, averaged across all the subjects, with respect to the number of the training examples of each class, for the starplus and twocategories datasets respectively. They show that the hierarchical GNB classifier is able to take advantage of the other subjects' data when the number of training examples is small, and is also flexible enough to reduce the contribution of the other subjects' data as the number of training examples increases.



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