

Feature-Task Co-clustering Regression in Multitask Learning applied to Word Meaning Representation in the Brain

Frequently, in multitask learning, a group structure can be identified among the tasks. Tasks within a group can be learned using approximately the same set of input features, whereas tasks from different groups depend on disjoint/nearly-disjoint sets of features. In many cases, the group structure among the tasks and the feature that are relevant to each group are both unknown. An example is clinical alarm pre-emption where the features represent patients' vital signs – heart rate, respiratory rate, blood pressure – while the outputs are flags marking clinical episodes (heart-attacks, seizures). Here, we focus on fMRI data, where one goal is to uncover the voxels that encode different semantic concepts.

We present Feature-Task Co-clustering Regression (FTCR), a method that discovers both the underlying group structure among the outputs and the relevant features for each group, offering experts valuable insight on the data. By imposing a block diagonal structure on the regression coefficients matrix, our approach reduces both the sample and computational complexity. The typical manner of retrieving two-mode clusters involves learning the coefficient matrix, then applying a co-clustering algorithm; the structure is obtained only after the regression step. This method offers no guarantee that, once the coefficient matrix is thus structured – keeping only the relevant features for a task group – the predictive accuracy is maintained. Our approach is therefore novel in providing an iterative linear regression method that learns nearly-disjoint groups of features/tasks while maintaining high predictive accuracy of the outputs, whilst needing fewer training samples.

FTCR starts by learning a sparse matrix of regression coefficient B using a lasso and a trace norm penalty. Then, it finds recurring sparsity patterns for rows/columns in the coefficient matrix to get a set of features and a set of tasks (S_1, T_1). It initializes a group coefficient matrix B_1 where the only non-zero elements are the row/columns in B corresponding to the set (S_1, T_1). Then it iterates the following steps: fixing B_1 , learns B_2 as the regression coefficients of $B_2X = Y - B_1X$, under the constraint that B_1 and B_2 are orthogonal; then fix B_2 , and learn B_1 similarly. It repeats the procedure until the residual $Y - (B_1 + B_2)X$ is small enough.

We apply FTCR on fMRI data from an experiment where subjects see word/picture combinations of a set of concrete objects. Each object is characterized by ratings along 218 semantic properties. We predict the ratings of a word from its brain image. Typically, different properties of objects are represented in different regions of the brain. We hypothesize that the pre-central regions encode manipulability properties and the para-hippocampal regions that encode shelter-like properties.

FTCR was shown to correctly recover group structure in artificial data. In the fMRI experiment, the algorithm does identify two distinct groups of tasks that correspond to manipulability and shelter properties. However, the regression coefficients corresponding to the two groups do not clearly distinguish between the two brain regions (pre-central and para-hippocampal), which suggests that these two regions might not be as functionally distinct in meaning representation as our hypothesis predicted.