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Dimensionality reduction and recurrent neural networks for feature rating prediction from fMRI data

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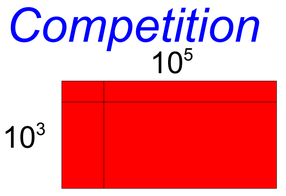
Task: Inferring Experience Based Cognition from fMRI - *Pittsburgh Brain Activity Interpretation Competition*

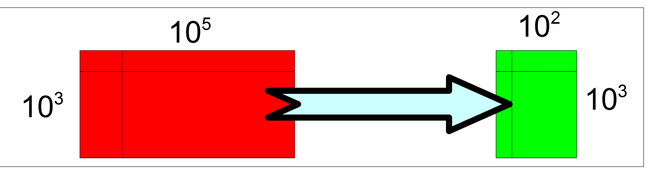
Datasets: 3 fMRI movies X 3 subjects (pre-processed & spatially normalized) each described by 19 feature ratings (Language, Laughter, Motion, Music, etc.) for ~10^3 timesteps



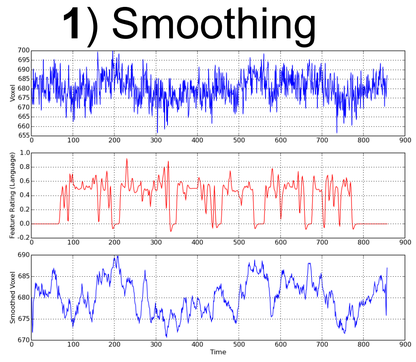
Idea: Predict independently each Feature Rating of each subject reducing the dimensionality of the problem

Pre-Processing

Idea: Reduce dimensionality of the problem shirinking 34x64x64=~10^5 voxels' values to ~10^2 values at each time step



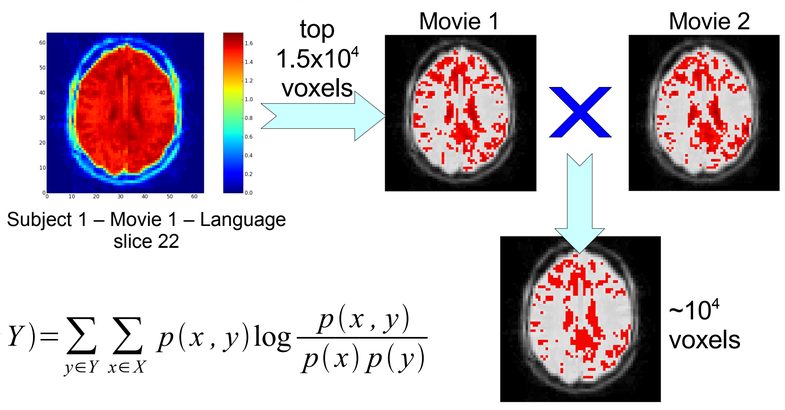
1) Smoothing



A low pass filter is applied to the original signal of each voxel (top) in order to remove high frequencies (bottom). High frequencies don't appear in feature ratings (middle)

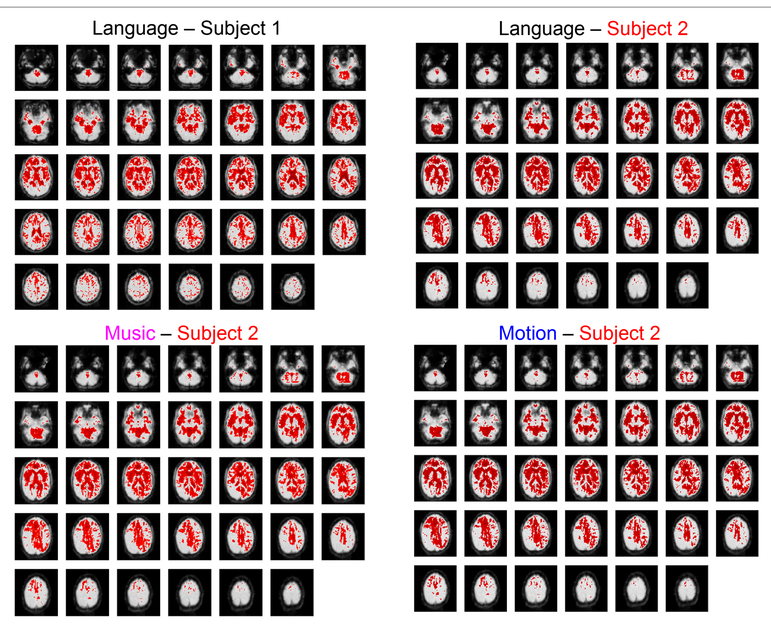
2) Mutual Information, Thresholds & Merge

Mutual Information measures "informativeness" of a voxel with respect to a target feature. Top 1.5x10^4 voxels are selected for movie 1 and 2 and and merged (intersection)



Subject 1 – Movie 1 – Language slice 22

$$I(X;Y)=\sum_{y\in Y}\sum_{x\in X}p(x,y)\log\frac{p(x,y)}{p(x)\,p(y)}$$

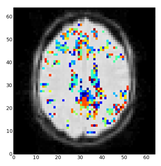


3) Clustering & Averaging

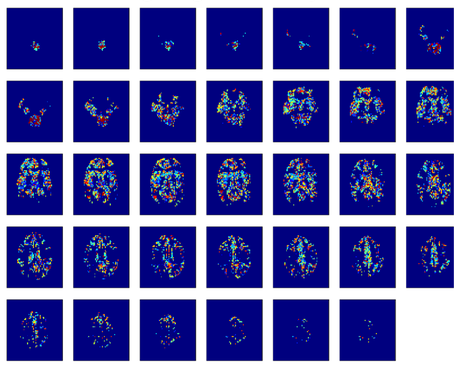
- K-Means clustering, K=200
- Trade off spatial distance and temporal correlation distance (1-r)

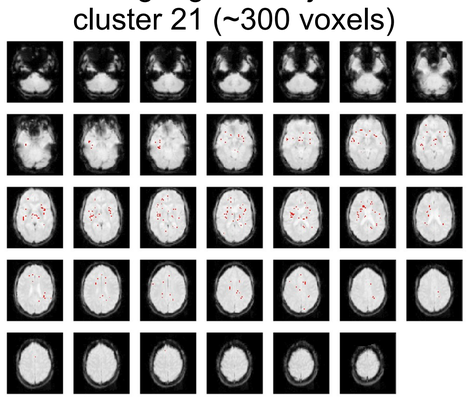
$$d=d_{spatial}^{\alpha}\left(1-r_{temporal}\right)^{1-\alpha}$$

- α = 0.5
- Correlation is computed on movie 1*+2*+3

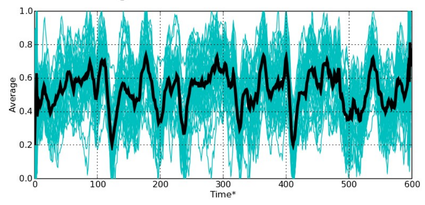


Subject 1 – Language slice 22

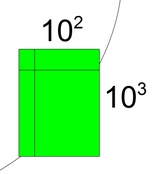




For each cluster compute average over its voxels

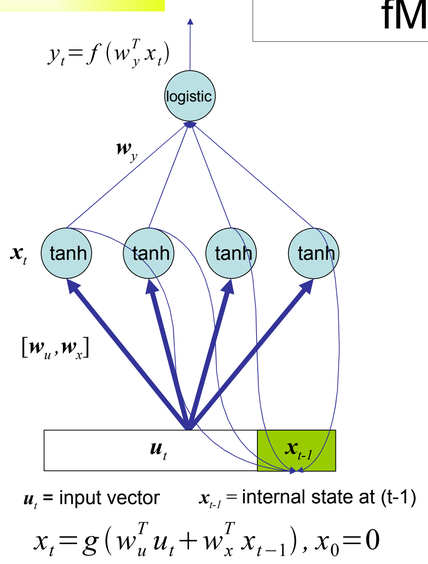


- 1 cluster → 1 average
- 1 movie = 200 averages X 10^3 timesteps



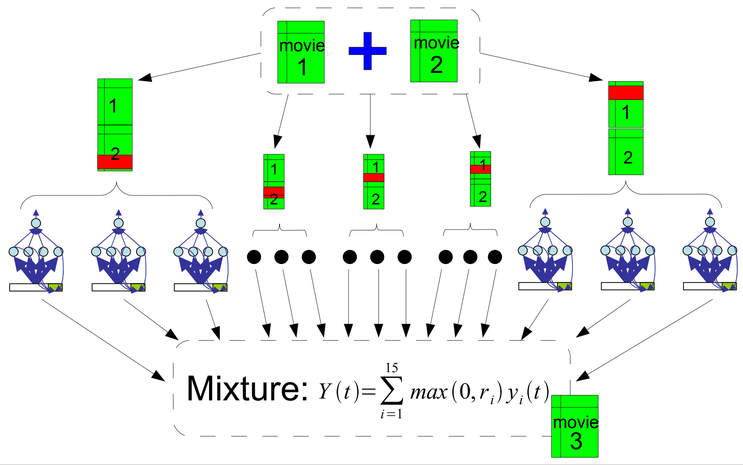
Prediction

Idea: use a mixture of **R**ecurrent **N**eural **N**etworks to predict a single feature rating from pre-processed fMRI dataset



- RNN pros:
  - simple/standard
  - non-linear
  - exploit time-dependence inputs (brain and movie inertia)
  - no need for priors on data distribution
- RNN cons:
  - RNN could overfit

Training (5-fold CV) and Mixing RNNs



Observations / Insights

- *easy* features (Faces, Language, etc.): 1 or 2 hidden units are good
- *difficult* features (Food, Attention, etc.): accuracy (low) independent of number of hidden units:
  - Pre-processing removed important information?
  - Information not present in fMRI data?
- NOTE: we don't exploit correlation between feature ratings

Conclusions

- Proposed method is very general: no hand tuning for subjects or feature ratings
- **AverageCorrelation>0.482** on base feature ratings using movie 1 and 2 (train set) to predict movie 3
- Pre-processing is more important than the prediction model