Deformation-Invariant Sparse Coding
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Motivation
How do we model population-level brain response to a given cognitive task such as reading sentences?

Challenge: Even if we pre-aligned brains (so everyone has the same brain), brain activations due to a cognitive task can vary in location in the normalized space!

Goal: Find correspondences between different subjects’ activation regions & find descriptions for each group region

Toy Example
Want to recover box and Gaussian bump

Model
Generative process for signal $n = 1, \ldots, N$:
1. Choose weights for each dictionary element
Example: $w_n = (0.3, 1.0)$
2. Form a weighted sum of dictionary elements
Example:
$$\sum_{k=1}^{K} w_{nk} D_k$$
3. Warp pre-image and add Gaussian noise
Example:
Encode each group region as a dictionary element!

$$y_n = \left( \sum_{k=1}^{K} w_{nk} D_k \right) \ast \Phi_n^{-1} + \text{noise}$$

Choice of Priors
• Weights $w_n$: sparse
• Deformations $\Phi_n$: exploit existing image alignment algorithms
  • recovery dictionary elements up to small deformation
• Dictionary elements $D_k$: sparse, smooth, localized, diverse

Goal: Find dictionary & deformations maximizing $p(B, \Phi \mid y)$
  • iterate between updating weights, deformations, dictionary

Results
Language processing data:
• Substantial functional variability!
• 82 subjects reading sentences vs. non-words
• Observed signals $y_n$ are z-statistic images from standard fMRI preprocessing
  • higher intensity at voxel implies higher statistical significance for language processing at that voxel

1. Estimated group regions agree with known literature
Spatial support of group regions (in different colors)

2. Estimated deformations more robust group effects
Statistical significance within group regions

Contributions
• Extended sparse coding to handle deformations
• Uses existing image alignment algorithms as subroutine
• Can be interpreted as aligning a group with images with spatially adaptive intensity equalization
• Applied model to functional neuroimaging data

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