Intelligent sparse representations for speech

or how I learned to stop worrying and love the noise

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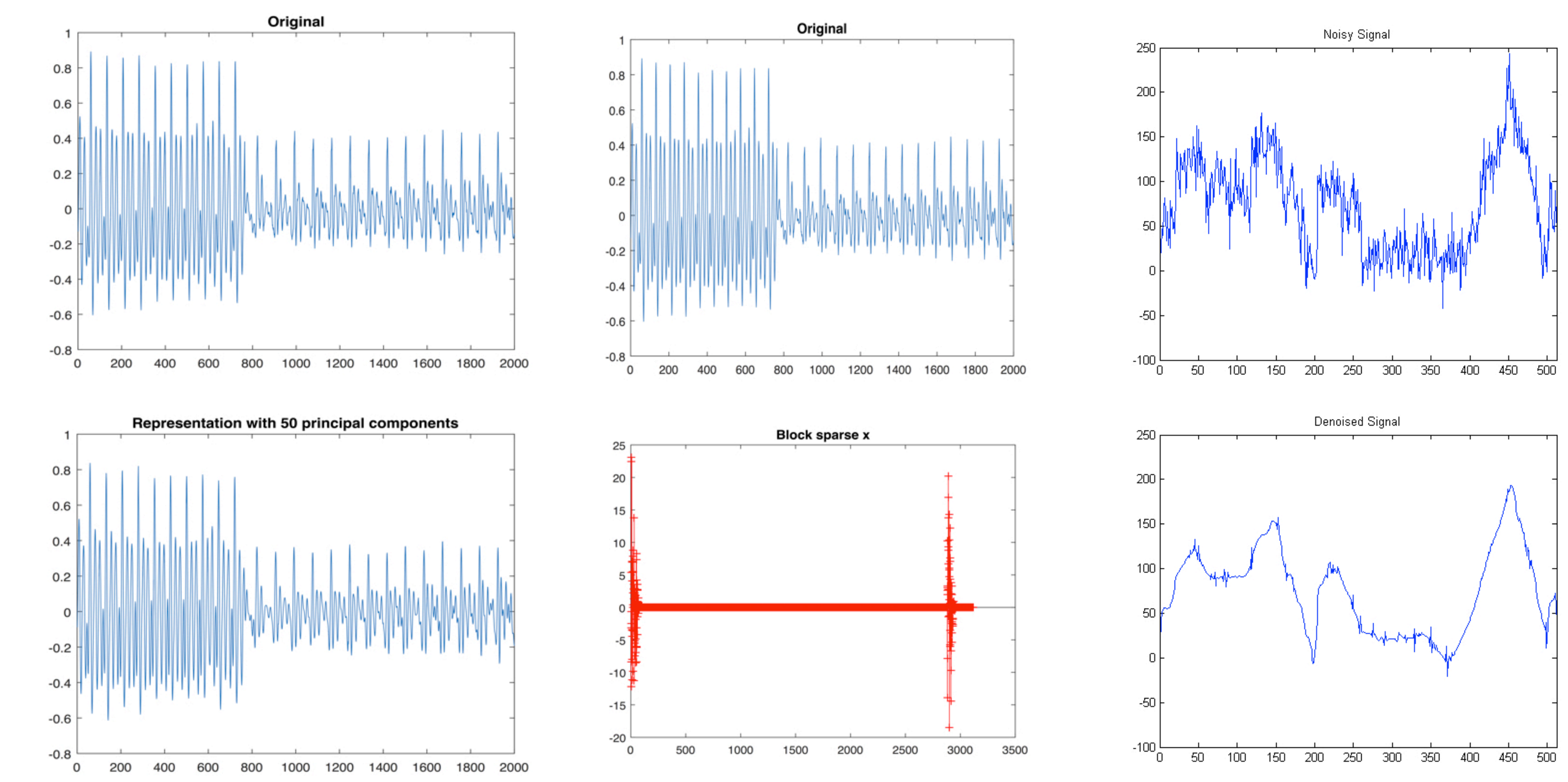
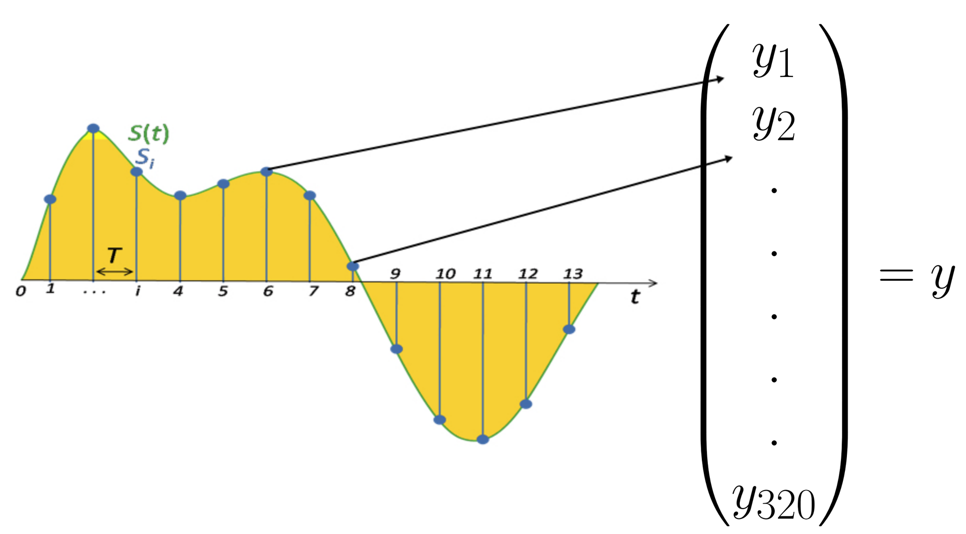
ENEE662: Convex Optimization Group:13

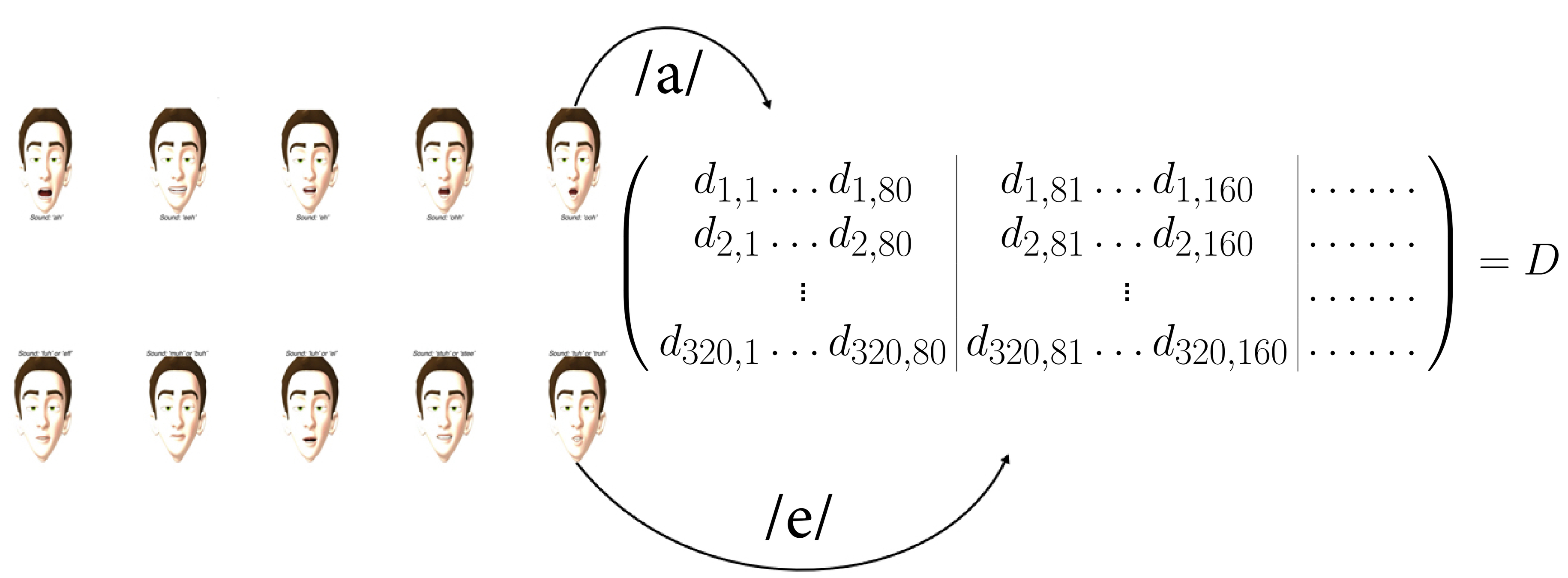
Goals



Sparse Representation Phoneme Identification Denoising

Introduction to Speech Processing





We have to find an x, such that $y = Dx$.

- If this x is sparse, we have compression
- If this x is block sparse, we have Phoneme Identification
- If y is a noisy signal, an x minimizing $||y - Dx||_2$ can be used to obtain a denoised signal $\hat{y} = Dx$

Questions

- Can we have an intelligent representation in a different domain that exploits certain properties of speech and allows for sparser representation?
- Can such a representation allow us to denoise these signals and identify phonemes present in the signal?
- If y is a noisy signal, does imposing sparsity constraints while estimation result in denoising?

Preprocessing

- *Discrete Cosine Transform* is performed on 20ms samples of a phoneme to obtain a spectrogram.
- *PCA* on the spectrograms of all the phonemes gives the dictionary D.
- **Objective:** To find a sparse vector x such that at most two phonemes are active in it and $Dx = \hat{y} \sim y$, the measured sample.

Convex Programming Formulation

$$\underset{x \in \mathbb{R}^n}{\text{minimize}} \quad \sum_{i=1}^{m} \sqrt{\sum_{k \in \text{ block } i} x_k^2}$$
$$\text{subject to} \quad \|Dx - y\|_2 < \epsilon$$

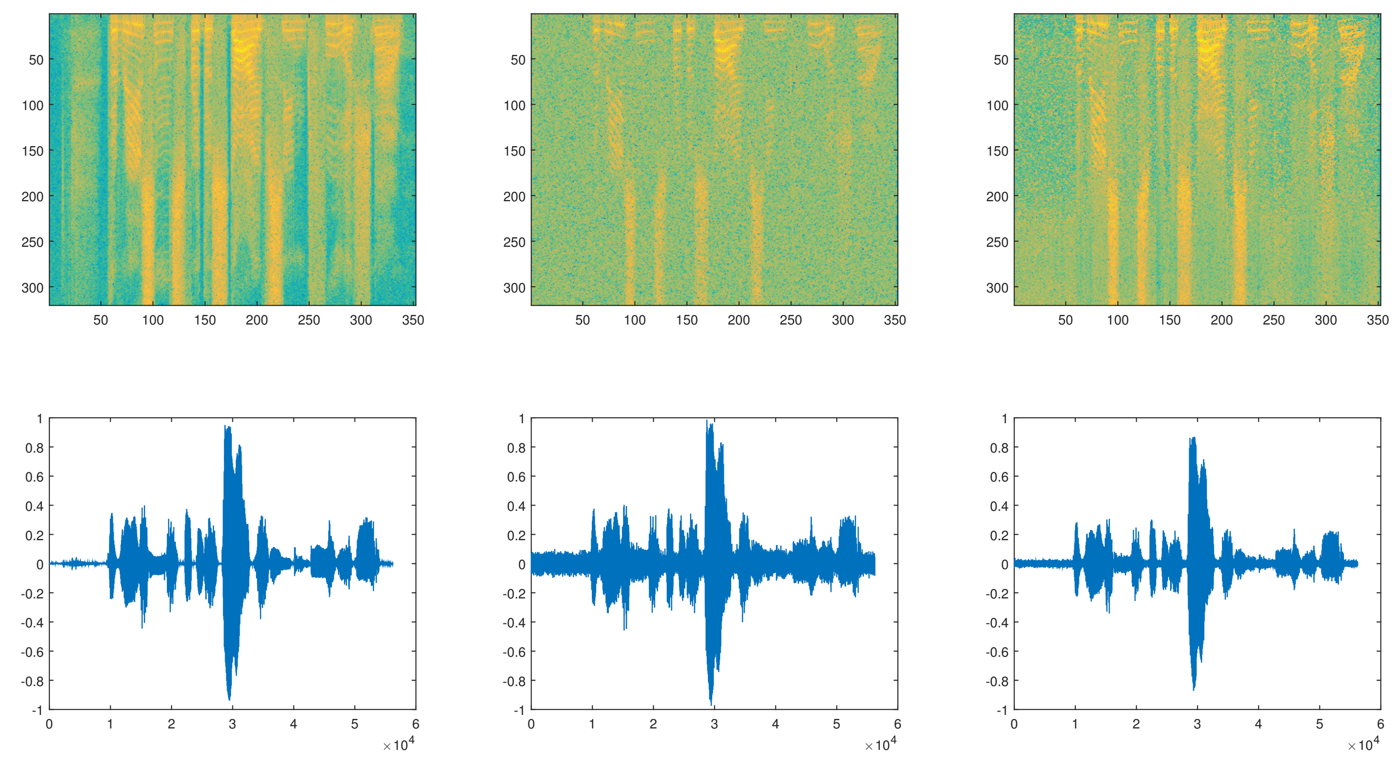
- The sparsity "$\ell_{2,0}$" norm minimization problem is relaxed to an $\ell_{2,1}$ norm minimizaton problem

Other Approaches

- *Lasso*: $\underset{x \in \mathbb{R}^n}{\text{minimize}} \ \frac{1}{2}\|Dx - y\|_2 + \alpha \|x\|_1$
- *Group Lasso*: $\underset{x \in \mathbb{R}^n}{\text{minimize}} \ \frac{1}{2}\|Dx - y\|_2 + \alpha \sum_{i=1}^{m} \sqrt{\sum_{k \in \text{ block } i} x_k^2}$
- We use ADMM for the above two problems. Sparsity improved by retaining the two most significant blocks
- *Greedy Algorithms*: Greedily choosing the best two blocks By the way of *Orthogonal Matching Pursuit*

Experimental Details

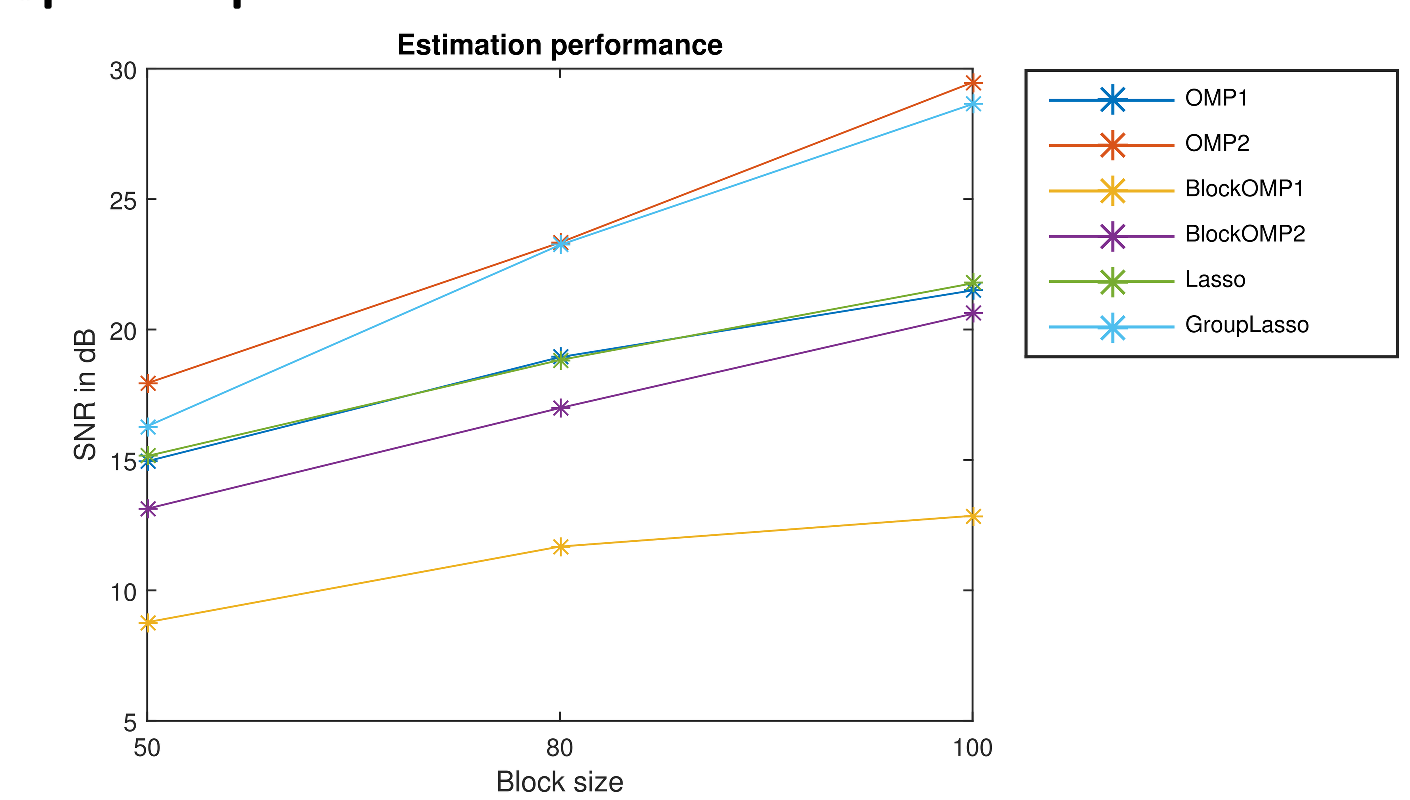
Example output



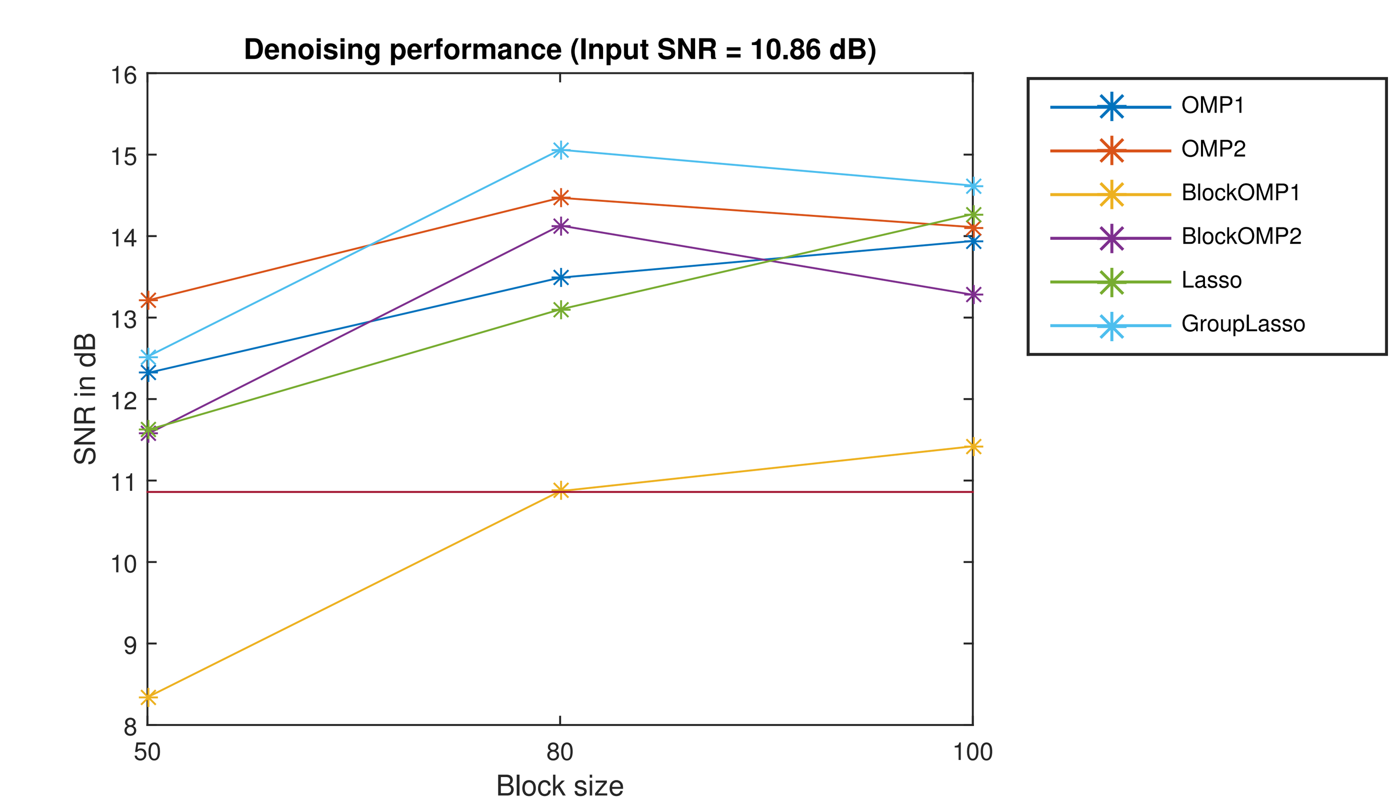
Original Noisy Estimated

Results

Performance of various methods for Estimation using Sparse representation



Performance of various methods for Denoising



$*$ Image Credits: Section 1-Noisy Signal: Ivan Selesnick Section 2-Sampling: Wikipedia. Phoneme Chart: Erin's Blog