Rethinking the CSC Model for Natural Images

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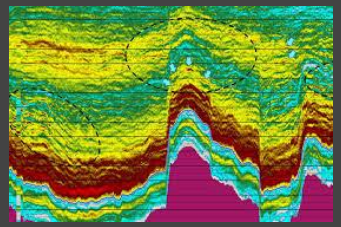
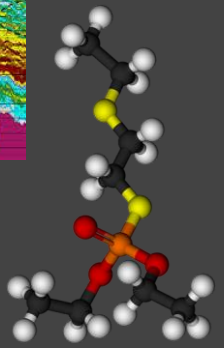
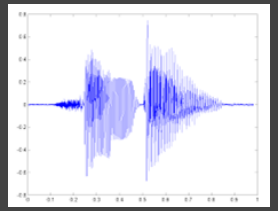
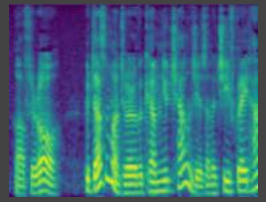
- Various data sources exist
- Data is structured
- This structure can be used in various signal/image processing tasks: denoising, deblurring, super-resolution, inpainting, signal separation, etc.

Model: a mathematical description of the underlying signal of interest, describing our beliefs regarding its structure

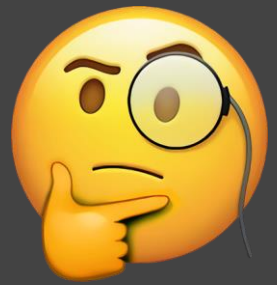


Rethinking the CSC Model for Natural Images

Why bother studying models? We have deep neural nets now!

- Still leads to state-of-the-art results in some image processing tasks
- The study of image models may lead to:
  - New architectures
  - Novel regularizations
  - Aid in ANN theoretical study



Rethinking the CSC Model for Natural Images

- Field of experts
- Total variation
- Gaussian mixture
- Wavelet decomposition
- Self similarity
- ...

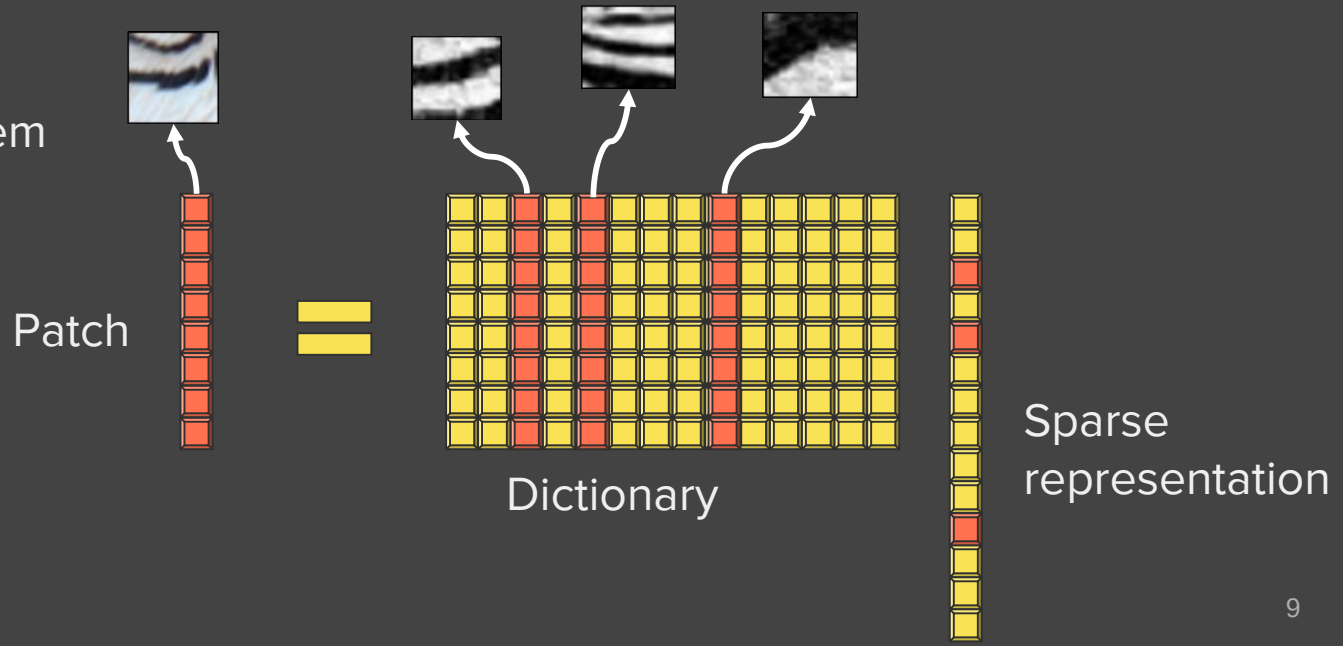





Rethinking the CSC Model for Natural Images

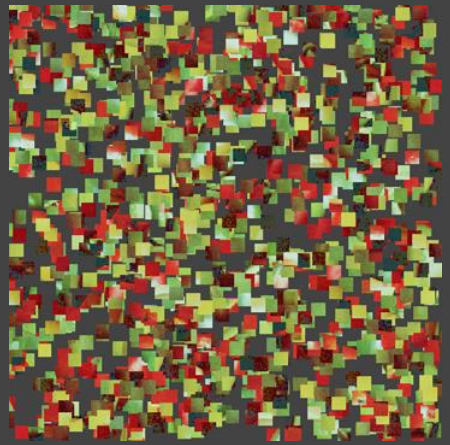
- Model 8x8 patches of images
- Sparse coding - find the sparsest combination that reconstructs the input signal
- Non-convex

  optimization problem



Rethinking the CSC Model for Natural Images

- Split an image to overlapping patches
- Denoise each patch
- Put patches into original place - average overlaps

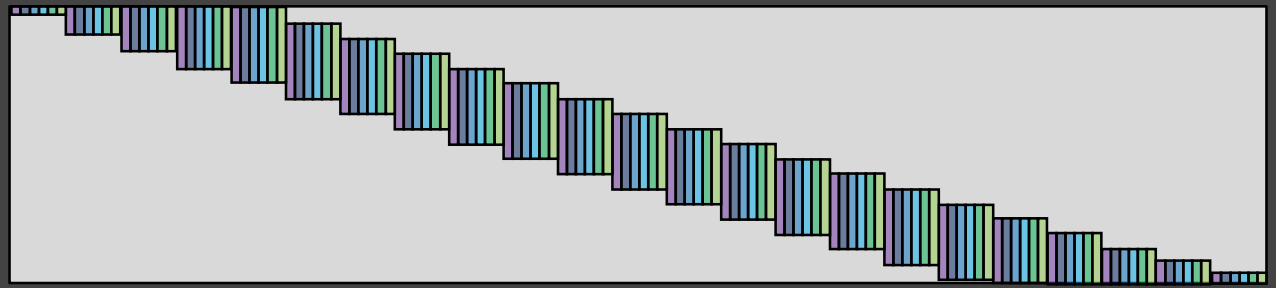


Towards a Global Model

- Working on patches falsely neglects their dependencies
- Why patches? Curse of dimensionality
- Some tried to overcome this flaw (e.g. EPLL)
- Another alternative — enforcing structure on a global dictionary

Rethinking the CSC Model for Natural Images

- CSC — a shift-invariant structure on the global dictionary
- The input signal is an entire image
- The dictionary's structure:



Rethinking the CSC Model for Natural Images

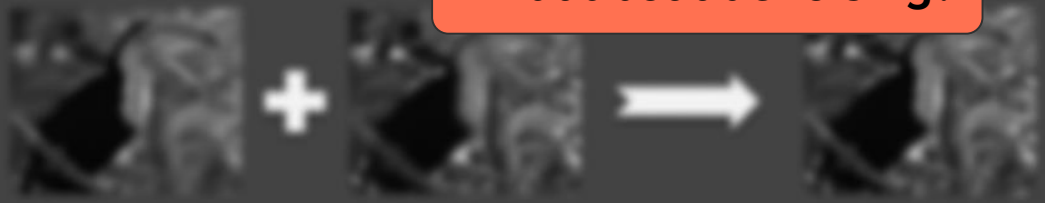
- Efficient global sparse coding algorithms exist
  - A. Szlam et al. (2010), F. Heide et al. (2015), B. Wohlberg et al. (2016), G. Silva et al. (2017), E. Plaut et al. (2019), E. Zisselman et al. (2019)
- Dictionary learning methods have been proposed
  - A. Szlam et al. (2010), V. Papyan et al. (2017), C. Garcia-Cardona et al. (2018), I. Y. Chun et al. (2018), E. Zisselman et al. (2019)
- Closely related to CNNs
  - V. Papyan et al. (2017)

Rethinking?

The CSC Model — Successful Use

- Cartoon-texture separation

- Image fusion



What about denoising?

- Single image super resolution

The CSC Model — Natural Image Denoising?

- Denoising is perhaps the simplest task
- CSC has lead to poor denoising results (worse than patch-based approaches)
- Some tried to “make it work” using preprocessing steps
  - No formal reasoning
  - Still inferior compared to patch-based methods (complexity and performance)
- So… can it work?

Rethinking the CSC Model for Natural Images

Why does the CSC denoise poorly?

We found two main reasons:

1. Properties of natural images, specifically their smoothness
2. A Bayesian perspective: Patch averaging = CSC MMSE approximation

These insights lead us to a novel MMSE approximation for the CSC model, outperforming previous methods

CSCNet — A Supervised Denoising Model

- A recurrent network architecture
- Inspired by the convolutional sparse coding optimization problem
- On par with other leading denoising methods
- Uses 90% less parameters

Time to Conclude

- This work exposed the limitations of the CSC model in representing natural images in the presence of noise
- Connection between local patch-based SC and global CSC

- Take-home lesson:

  If something persistently doesn’t work — try proving it can’t


Thank
you!