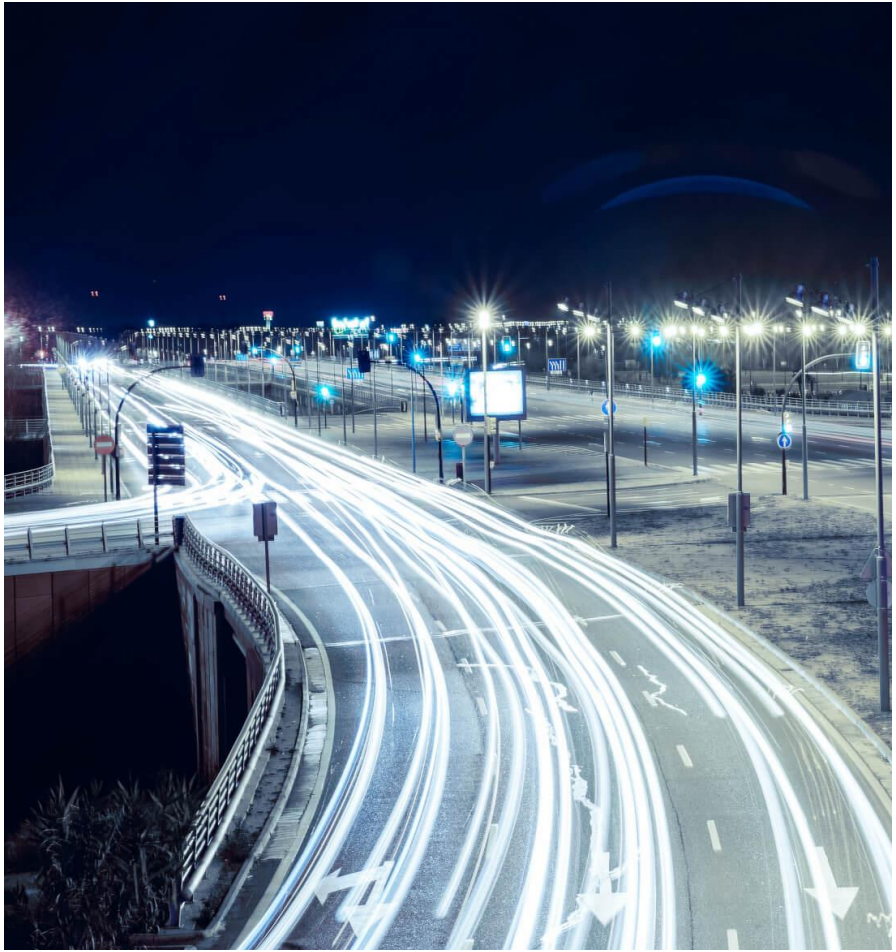
Denoising Images Using Sparse Representation

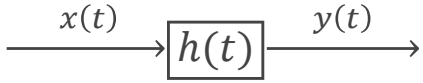
Presented By: Arsalan Barolia

Table of Contents



Background

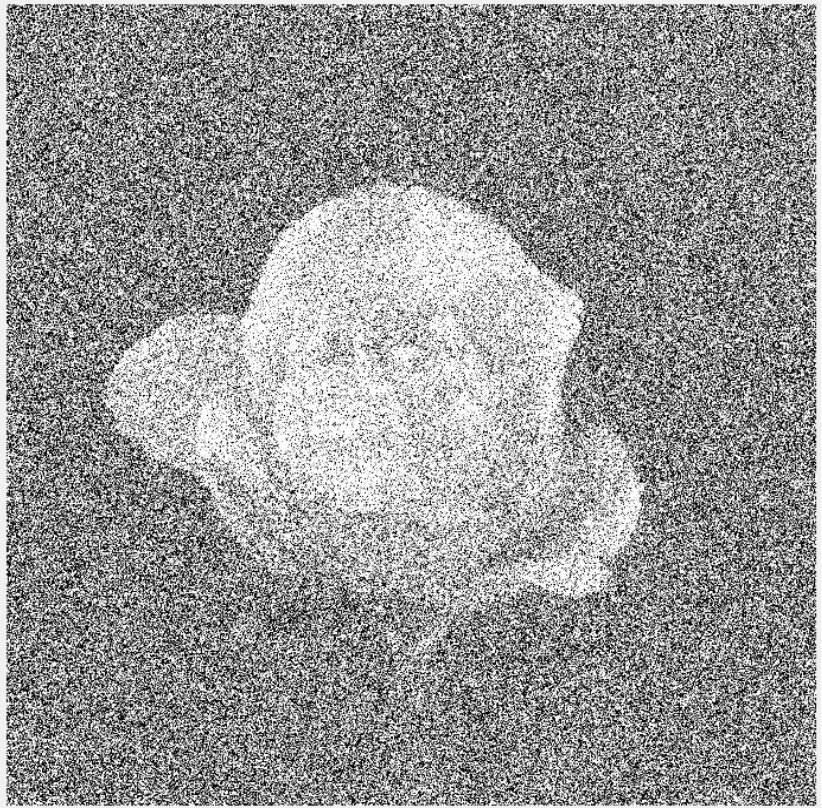
- Images display important information
- Useful for identifying various things
  - Especially in the medical field
- Noise → Unwanted



- Can use different filtering techniqes to remove noise

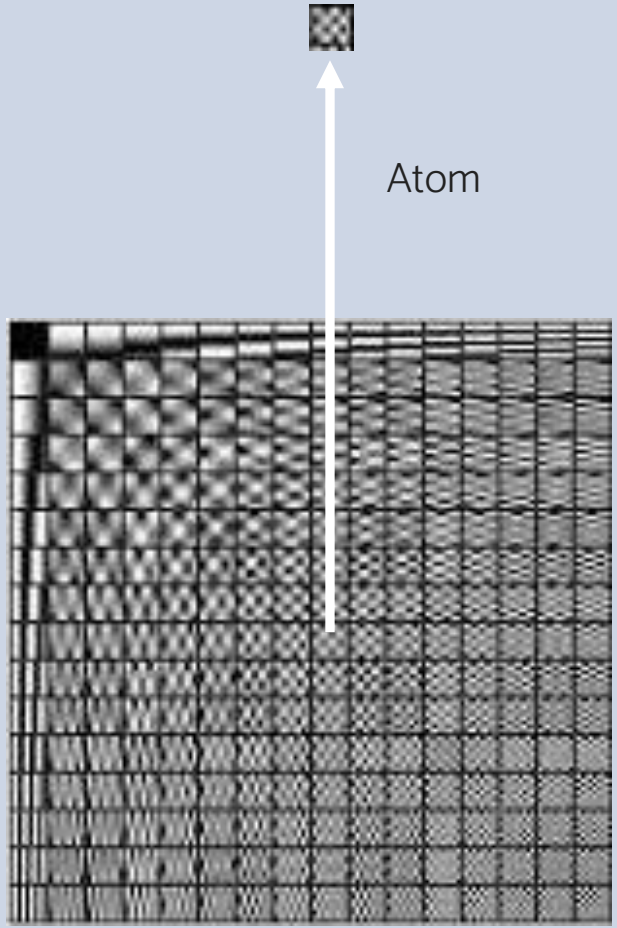
Original Image

Gaussian Noise Image with mean = 0.5 and variance = 0.5



What is Sparse Representation?

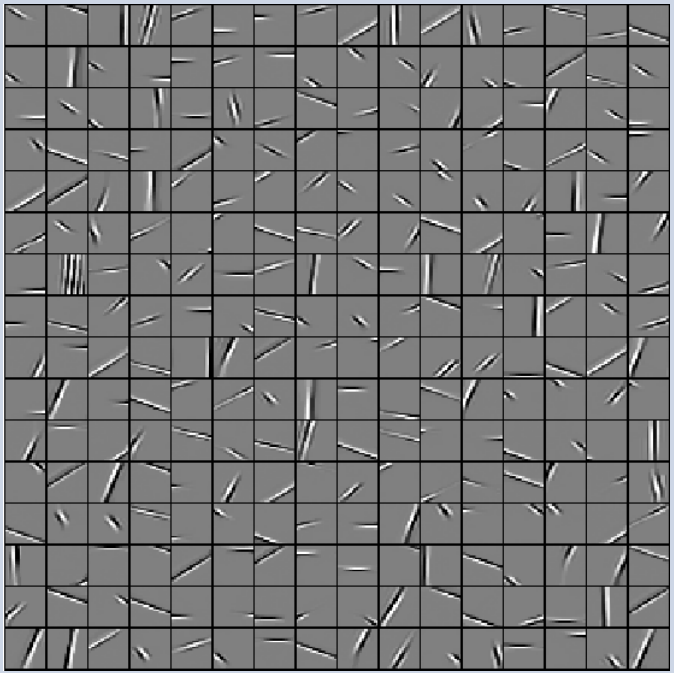
- Atoms → Entries in the dictionary
- Dictionaries → A collection of atoms
- Helps solve systems of linear equations
- Can be paired with other methods to improve denoising



How It Works

- Finds patterns in the images that are ‘regular’ and ‘uniform’
    - Areas with no noise present

- Problem → Will be hard to use for geometric shapes
    - Reason for the dictionaries



Denoising Methods

- Will be discussing:
  - Block Matching
  - Segmentation
  - Redundant Representation
  - Learning/Adaptive Dictionaries

The Problem with existing denoising method

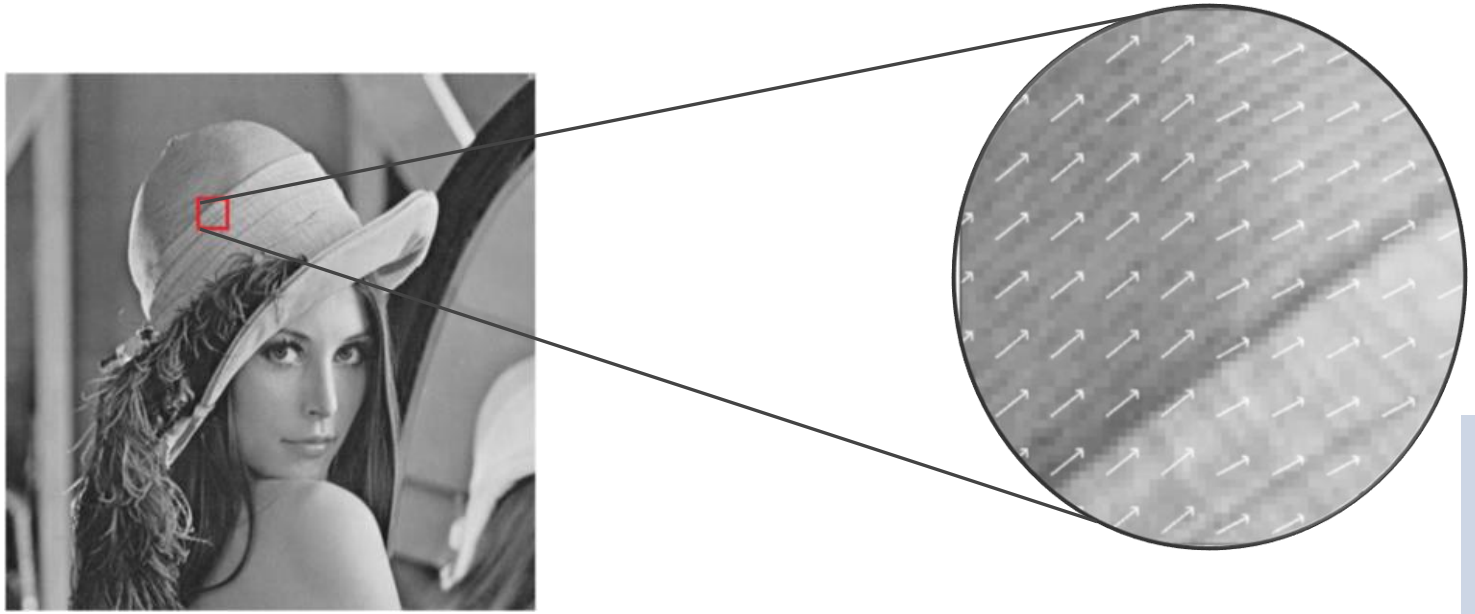
- Written by Hamid and Seyede

- 1st Disadvantage → Elad and Aharon created a dictionary to denoise images using the K-SVD algorithm
    - Includes redundancy in a global Bayesian objective and sparsity
        - Takes form of a random function
        - Causes biases based on one's belief of what the function should be

- 2nd Disadvantage → Overfitting occurs
    - The model "memorized" the data that was given
    - Neglects to learn the relationship of the function.

Block-Matching and Sparse Representations

- Proposed Method → Incorporates the Bandelet Transform with CS and Block Matching
  - Bandelet Transform beneficial tool for identifying edges and texture in an image
  - Identify the geometric flow of vectors using the grey levels in a local area



Block Matching and Sparse Representations

- Denoising techniques that finds similar grey level blocks around an image
  - Helps with edge identification and preservation

- Once these groups are identified they are grouped
  - Variety of methods for grouping:
    - Vector quantization
    - k-means clustering
    - Fuzzy clustering
    - Self-Organizing maps

Proposed Method

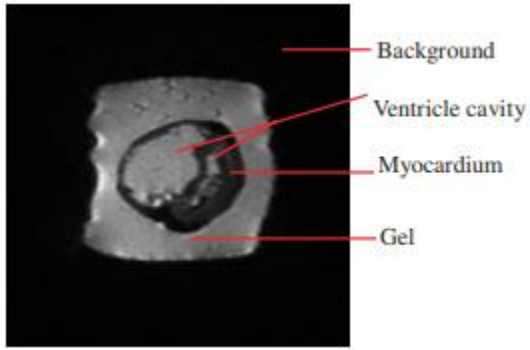
- 1st Step: Use block matching technique to determine where similarities are in the image
- 2nd Step: Group using k-means to find indices for each group patch
- 3rd Step: Use overcomplete Discrete Cosine Transform (DCT) dictionary
  - Greatly used in data compression and converting data like pixels and waveforms into frequency components
  - Using the TwIST (two-step iterative shrinkage/thresholding) algorithm
- Benefit using TwIST algorithm is that it is ideal for optimizing images as it uses values of u that are from the previous and current iterations as oppose to IST (Iterative shrinkage/thresholding) algorithm that takes inputs only from the current iteration process

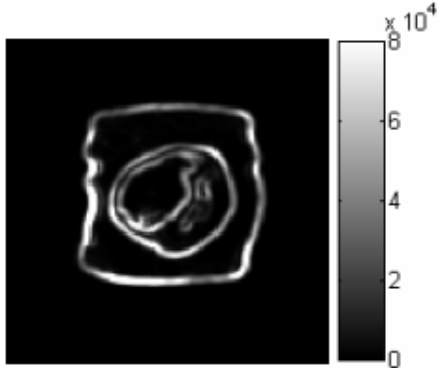
Denoising Cardiac Diffusion Tensor Magnetic Resonance Images (DT-MRI)

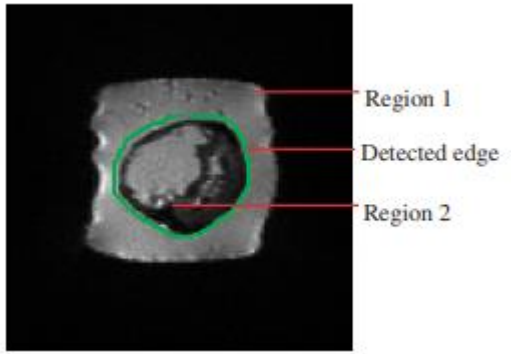
- Denoising medical images is very important
- The DT-MRI is very noise sensitive and can cause numerous systemic errors in subsequent parameter calculations
- Unwanted noise caused by pumping of the heart or movement of the patient
- Proposes to use segmentation and sparse representation to remove noise from the image

Segmentation with Sparse Representation

- Segmentation is used to make atoms more adaptive in the dictionary
- Various segmentation methods but the one used in the paper was edge detection by thresholding
- Able to detect edges and regions in an image
- NSD = Non-stationarity detection
  - Used to make independent components







Denoising with Segmentation and Sparse Representation

- Atoms are gradually cycled until denoising is achieved
- Current techniques used is partial differential equation (PDE) and wavelet filter
- **PDE:**
  - Good → Edge preservation
  - Bad → Degrades image with high noise levels
- **Wavelet filter:**
  - Good → Overall good image quality in terms of denoising
  - Bad → Elements and noise are convolved resulting in blurriness
    → Estimating threshold

Pre-built Dictionary vs. Adaptive Learning Dictionary

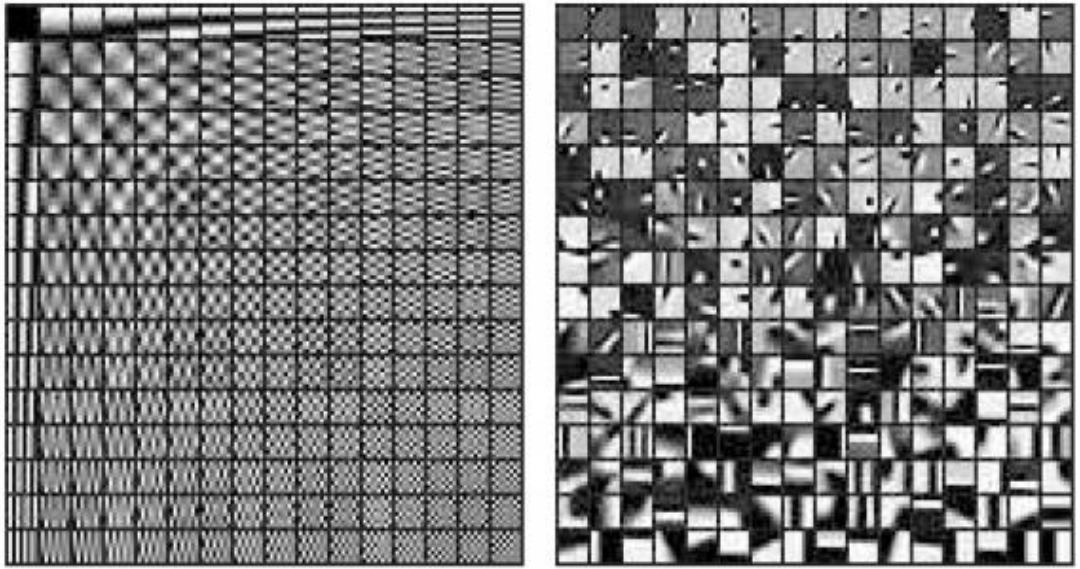
- Denoise images with Gaussian additive noise

$$y = x + v$$

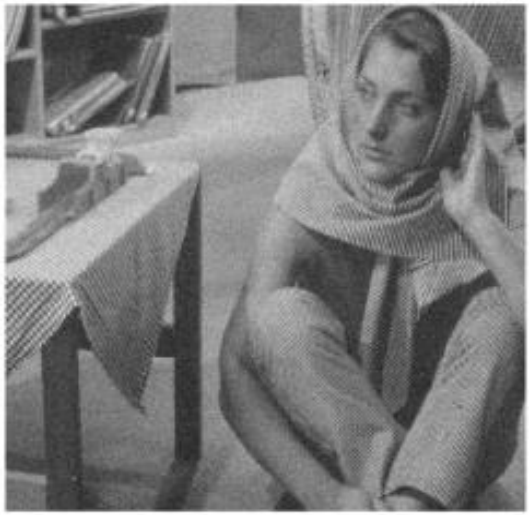
- Typically DCT dictionary would be used for all images, but discrepancies would be seen
- Roth and Black, wanted to create a method that implemented dictionary learning.

Comparison

- Using DCT dictionary → ‘Generic’ Method
- Using Adaptive Learning Dictionary → ‘Global’ Method



Original Image



Additive Noise

SNR: 28.8528 dB
Adaptive Dictionary

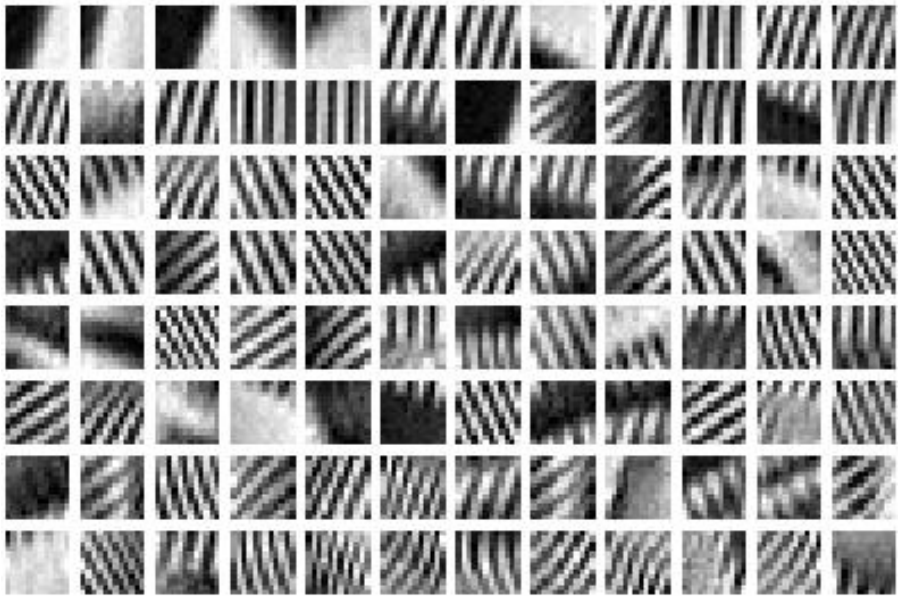
SNR: 30.8295 dB
Pre-defined dictionary

Implementation

- Block Matching with sparse representation implementation by Tampere University of Technology
- Recap of Block Matching and Sparse:

PSNR

Dictionary Example



Conclusion

- Sparse coding is better when paired with other methods
- Images are sensitive to noise and can appear grainy
- Thus, constantly need to adapt our current methods of denoising to better suit every image

THANK YOU

Any Questions?