Report

CS 736 – Medical Image Computing

Assignment 2

Instructor: Dr. Suyash Awate

By,

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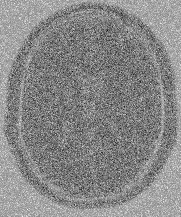
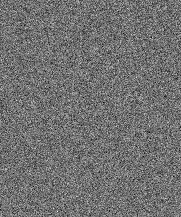
Submission Date: 22/02/2020

# Notes

1. The code is written in Python 3.6. The following libraries are used and hence are necessary for the code to work seamlessly:
   1. matplotlib
   2. numpy
   3. os
   4. pillow
   5. scipy
   6. cv2
   7. h5py
2. We perform serial updates on the image instead of parallel updates.
3. The range of image intensities is .
4. For denoising, we’ve applied the algorithm for 5 times.
5. For hyper-parameter optimization, we take steps of in the range of and find the minimum.
6. The results (images) are saved in “results” folder, in case, the images in the report aren’t up to the desired resolution.

# Observations

1. We observe that the noise model is not additive Gaussian. We verified based on the following experiment. Take the noisy image (), assumed to be denoised by additive Gaussian noise on noiseless image (). That is, . Hence if we subtract noisy image from the noiseless image, we should get a pure gaussian distribution . An example is given below. Given, such a case, the looks like pure noise, like the image on the left below.



But, in our case, when we subtract the noisy image from noiseless image, we get the image on the right. Hence, this shows that variance of the noise is dependent on the intensity of the image and hence, it couldn’t be additive Gaussian noise. The noise could not be additive Gaussian.

# Prior: Quadratic

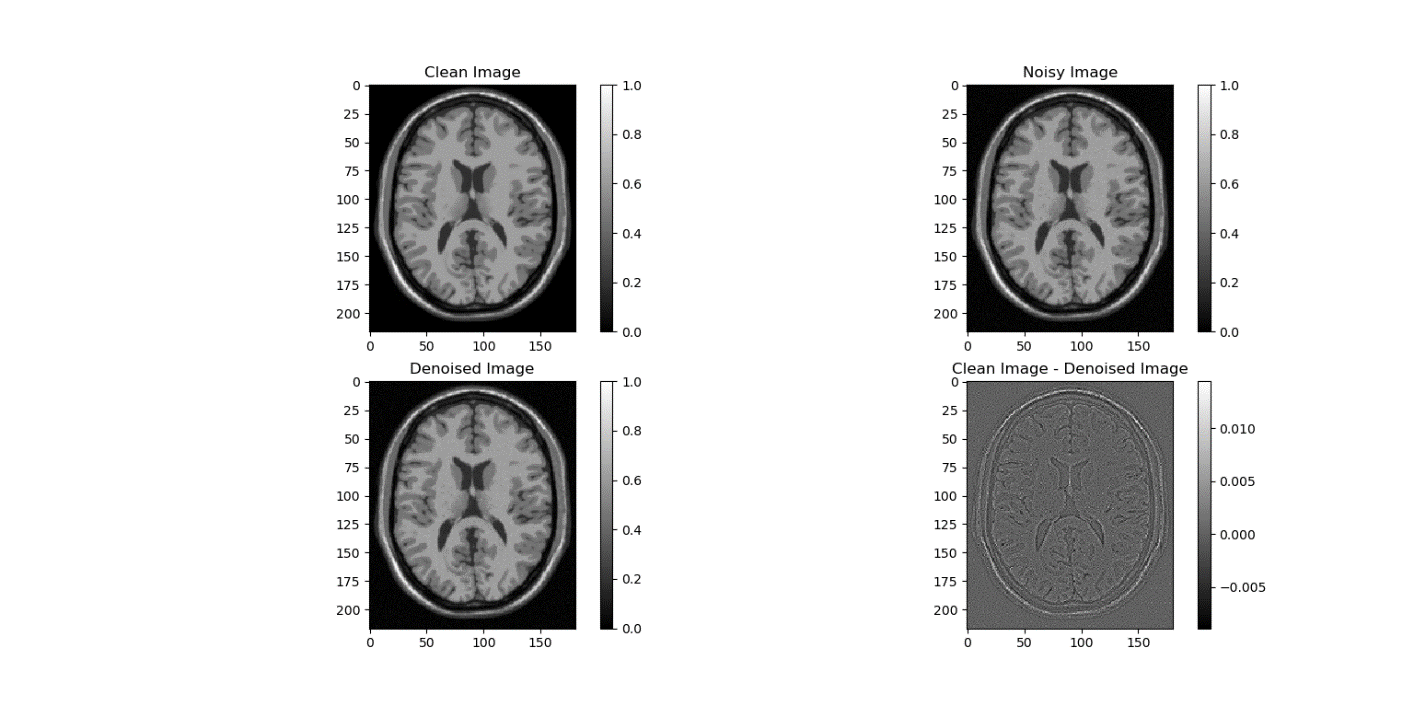
## Noise Level: Low

Assumed variance:

1. The Relative Root Mean Square Error (RRMSE) between the denoised image and noiseless image is .
2. Optimal Parameters
   1. Beta :
   2. For , RRMSE: 0.049
   3. For , RRMSE: 0.049

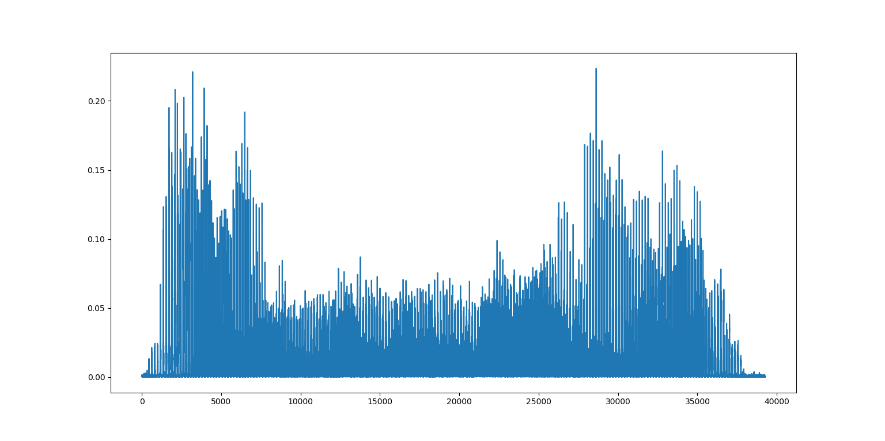
The difference was insignificant (< )

1. Denoised Image
2. Top Left: Noiseless Image
3. Top Right: Noisy Image
4. Bottom Left: Denoised Image
5. Bottom Right: Difference between Denoised and Noiseless Image



1. Plot of objective function vs iteration

This is after updating every pixel, 1 run



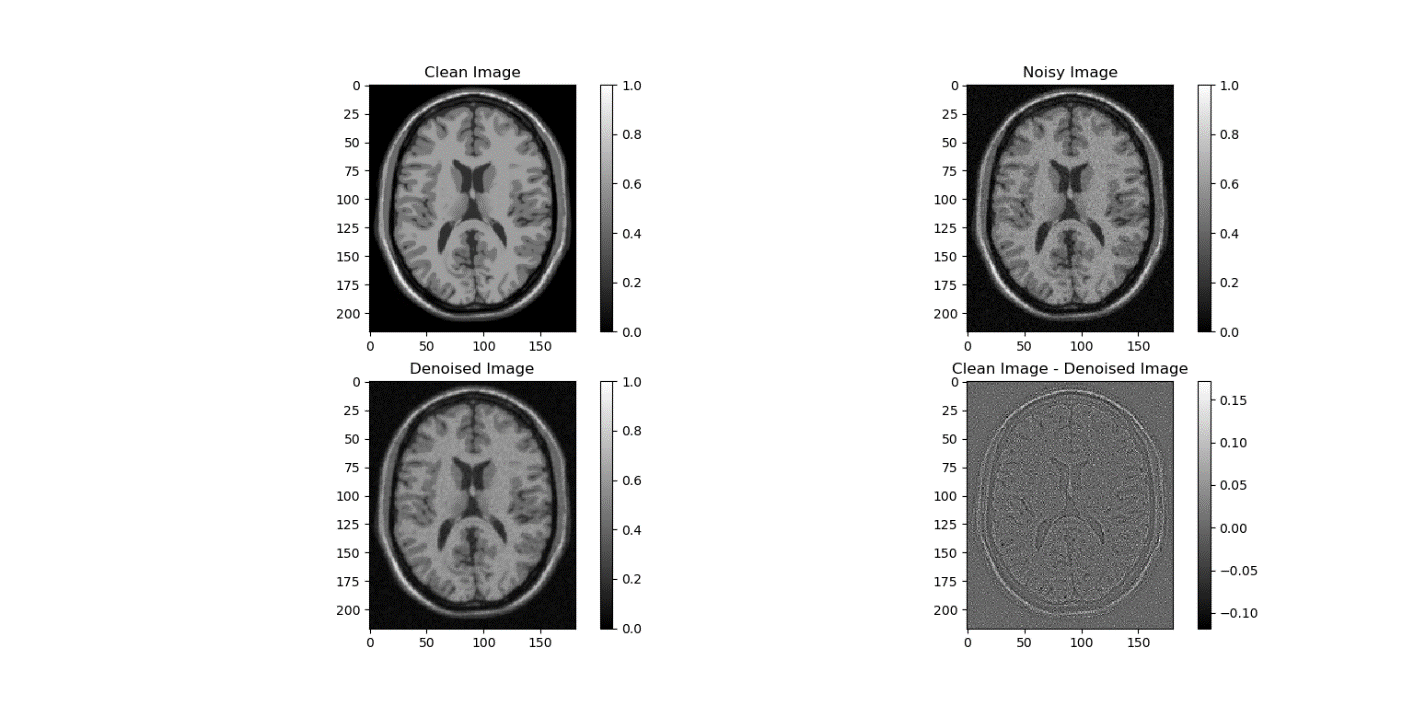
## Noise Level: Medium

Assumed variance:

1. The Relative Root Mean Square Error (RRMSE) between the denoised image and noiseless image is .
2. Optimal Parameters
   1. Beta :
   2. For , RRMSE: 0.114
   3. For , RRMSE: 0.119

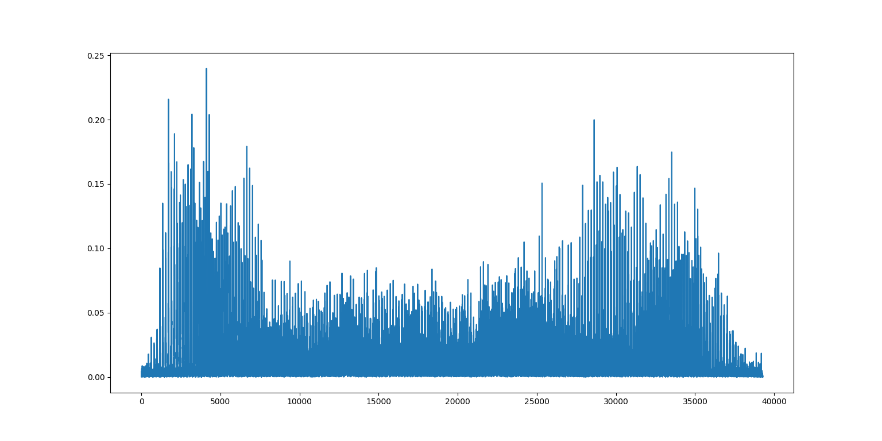
The difference was insignificant (< )

1. Denoised Image
   1. Top Left: Noiseless Image
   2. Top Right: Noisy Image
   3. Bottom Left: Denoised Image
   4. Bottom Right: Difference between Denoised and Noiseless Image



1. Plot of objective function vs iteration

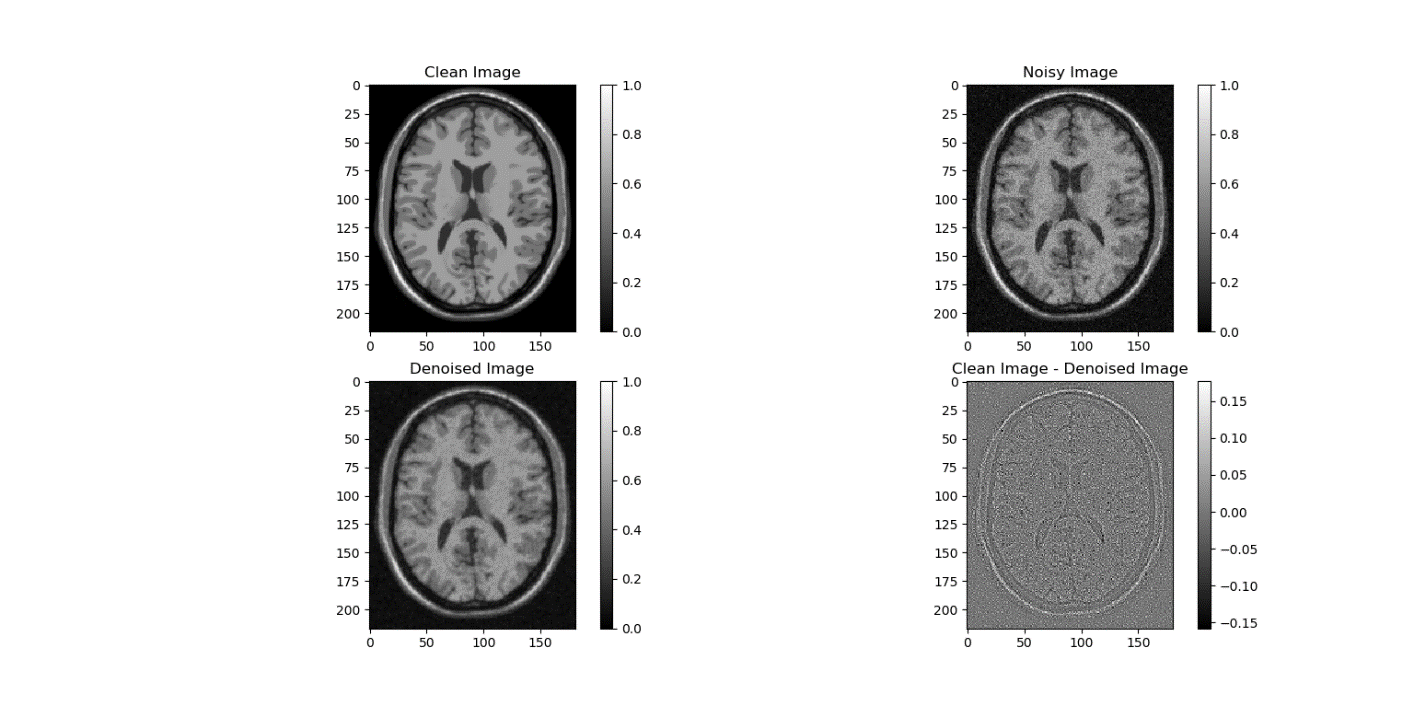
This is after updating every pixel, 1 run



# Noise Level: High

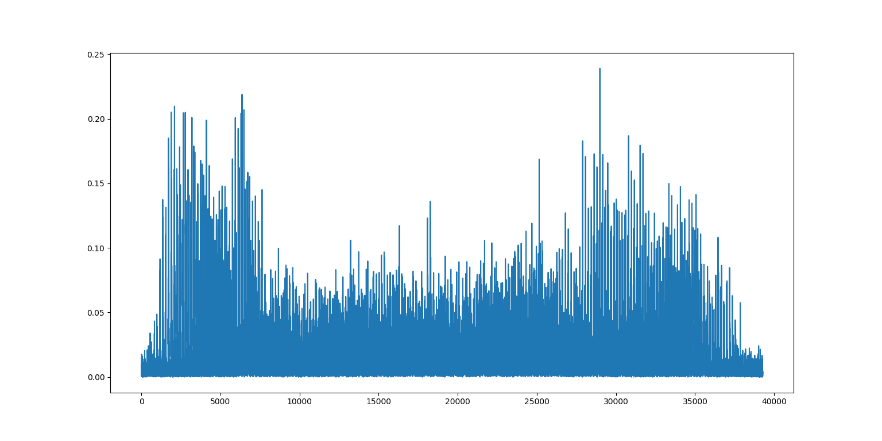
Assumed variance:

1. The Relative Root Mean Square Error (RRMSE) between the denoised image and noiseless image is .
2. Optimal Parameters
   1. Beta :
   2. For , RRMSE: 0.123
   3. For , RRMSE: 0.131
3. Denoised Image
   1. Top Left: Noiseless Image
   2. Top Right: Noisy Image
   3. Bottom Left: Denoised Image
   4. Bottom Right: Difference between Denoised and Noiseless Image



1. Plot of objective function vs iteration

This is after updating every pixel, 1 run

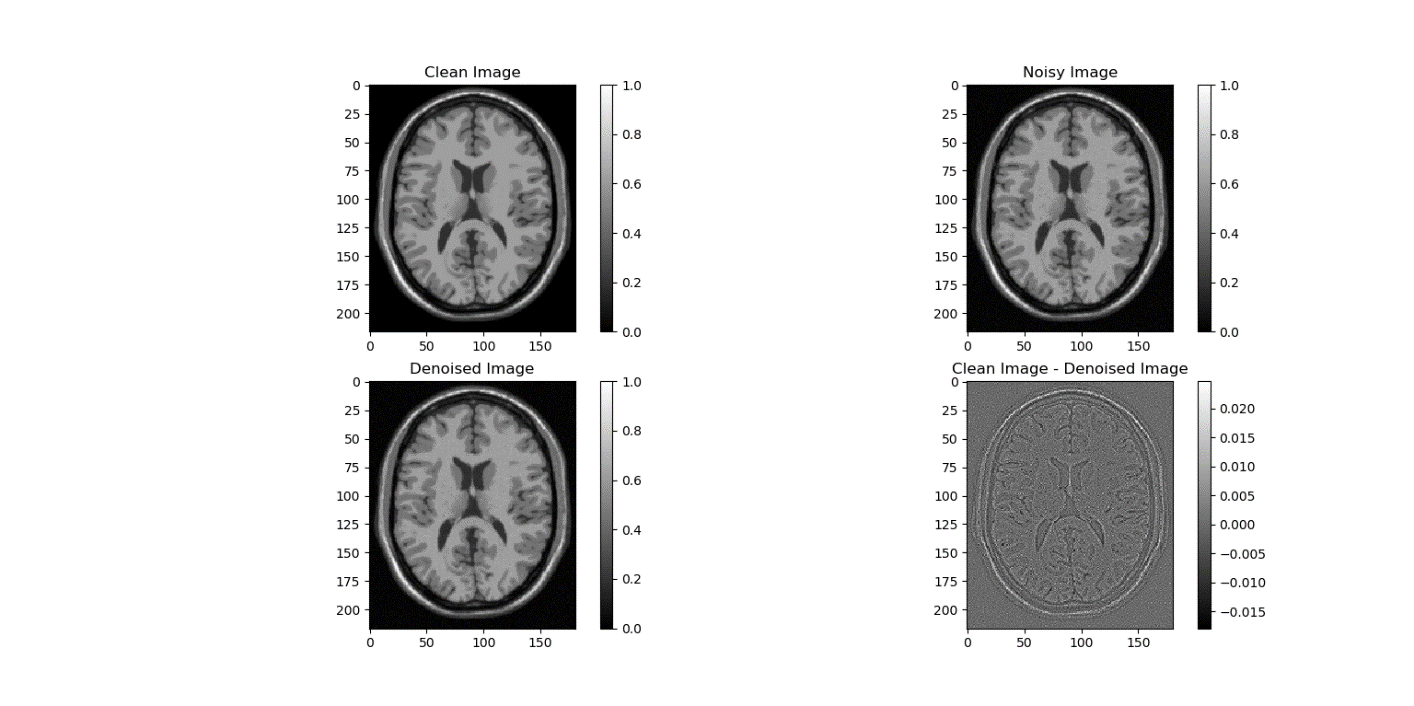


# Prior: Discontinuity Adaptive

## Noise Level: Low

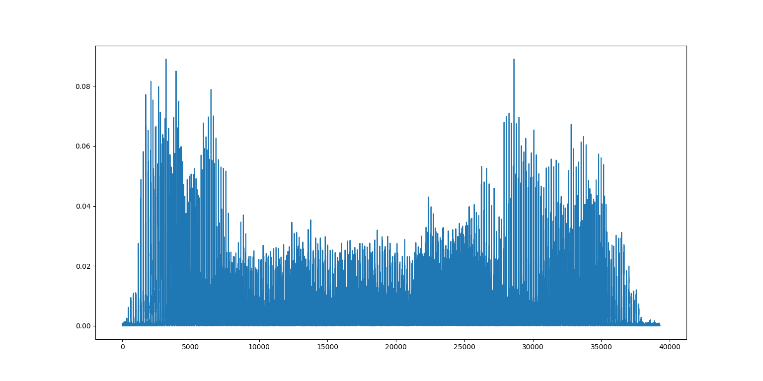
Assumed variance:

1. The Relative Root Mean Square Error (RRMSE) between the denoised image and noiseless image is .
2. Optimal Parameters
   1. (Beta, Gamma) : (
   2. For (, RRMSE: 0.046
   3. For (, RRMSE: 0.045
   4. For (, RRMSE: 0.045
   5. For (, RRMSE: 0.046
3. Denoised Image
   1. Top Left: Noiseless Image
   2. Top Right: Noisy Image
   3. Bottom Left: Denoised Image
   4. Bottom Right: Difference between Denoised and Noiseless Image



1. Plot of objective function vs iteration

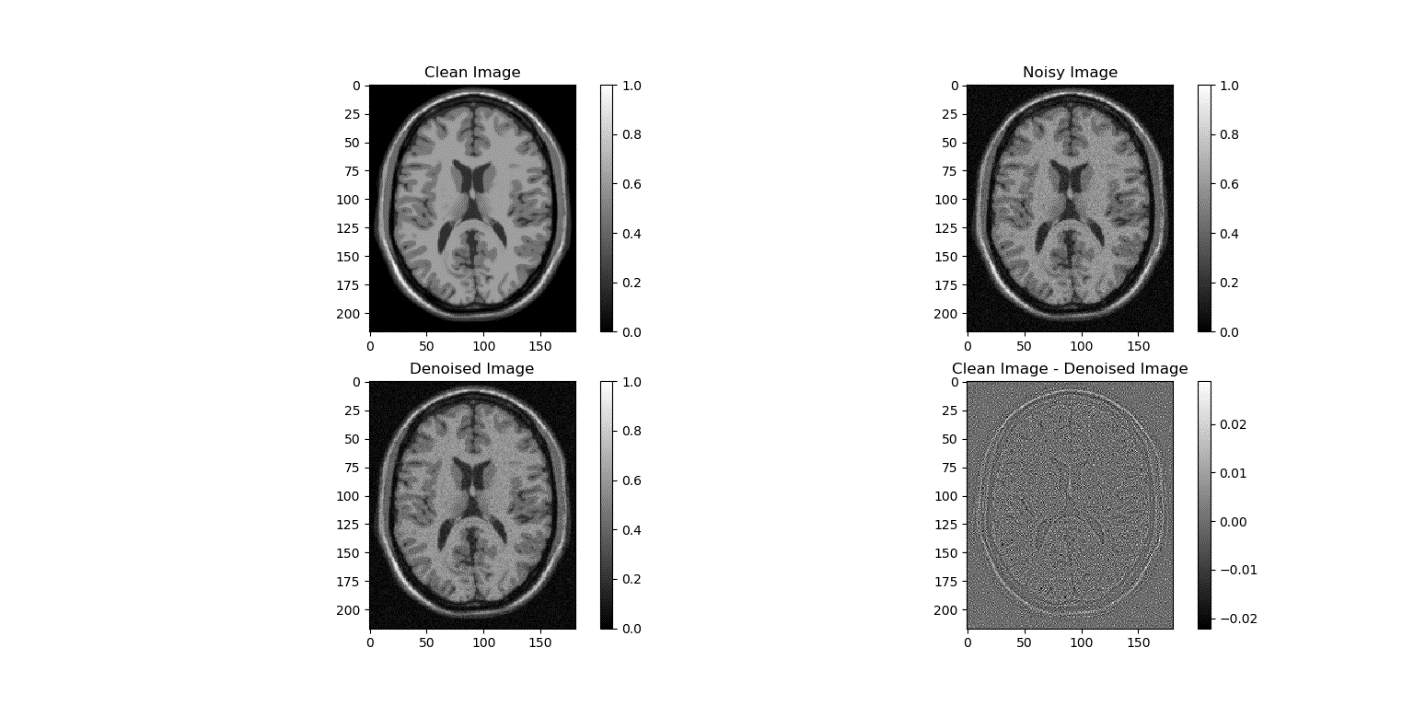
This is after updating every pixel, 1 run



## Noise Level: Medium

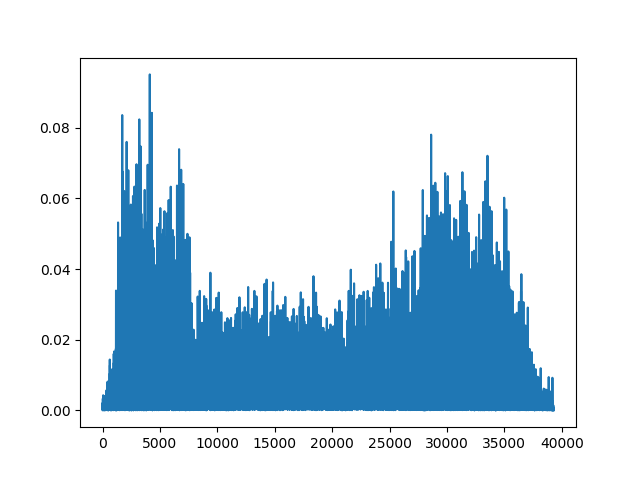
Assumed variance:

1. The Relative Root Mean Square Error (RRMSE) between the denoised image and noiseless image is .
2. Optimal Parameters
   1. (Beta, Gamma) : (
   2. For (, RRMSE: 0.124
   3. For (, RRMSE: 0.116
   4. For (, RRMSE: 0.118
   5. For (, RRMSE: 0.118
3. Denoised Image
   1. Top Left: Noiseless Image
   2. Top Right: Noisy Image
   3. Bottom Left: Denoised Image
   4. Bottom Right: Difference between Denoised and Noiseless Image



1. Plot of objective function vs iteration

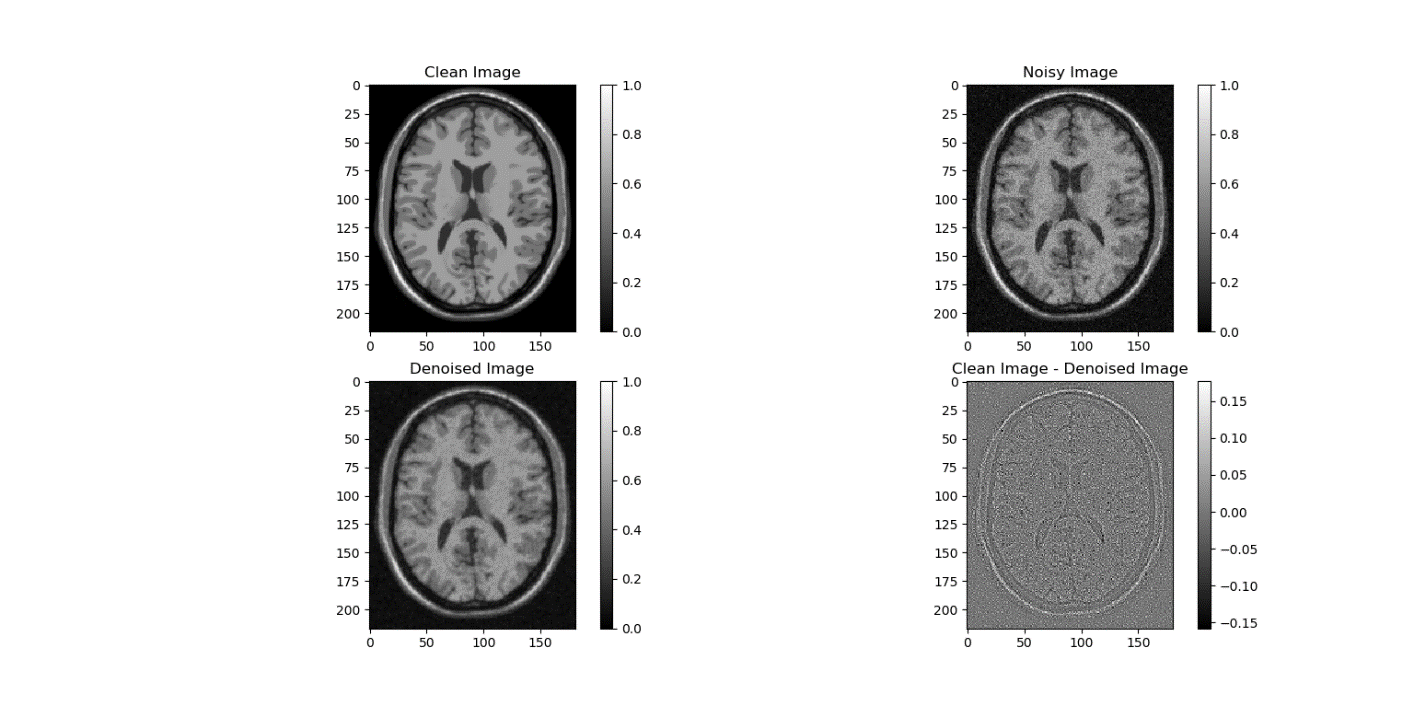
This is after updating every pixel, 1 run



## Noise Level: High

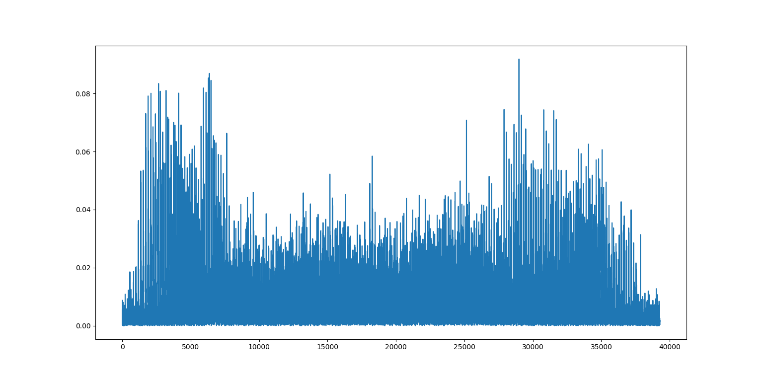
Assumed variance:

1. The Relative Root Mean Square Error (RRMSE) between the denoised image and noiseless image is .
2. Optimal Parameters
   1. (Beta, Gamma) : (
   2. For (, RRMSE: 0.14
   3. For (, RRMSE: 0.132
   4. For (, RRMSE: 0.136
   5. For (, RRMSE: 0.141
3. For (, RRMSE: Denoised Image
   1. Top Left: Noiseless Image
   2. Top Right: Noisy Image
   3. Bottom Left: Denoised Image
   4. Bottom Right: Difference between Denoised and Noiseless Image



1. Plot of objective function vs iteration

This is after updating every pixel, 1 run

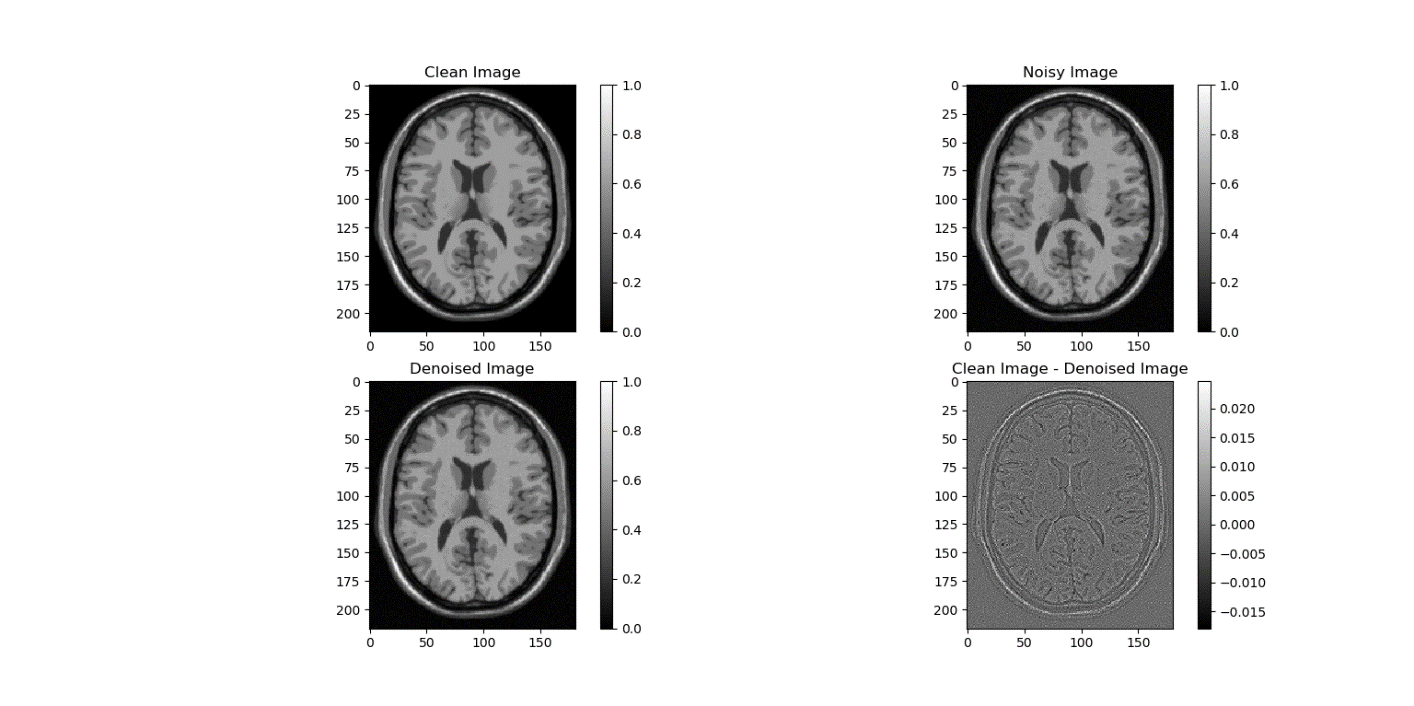


# Prior: Discontinuity Adaptive Huber

## Noise Level: Low

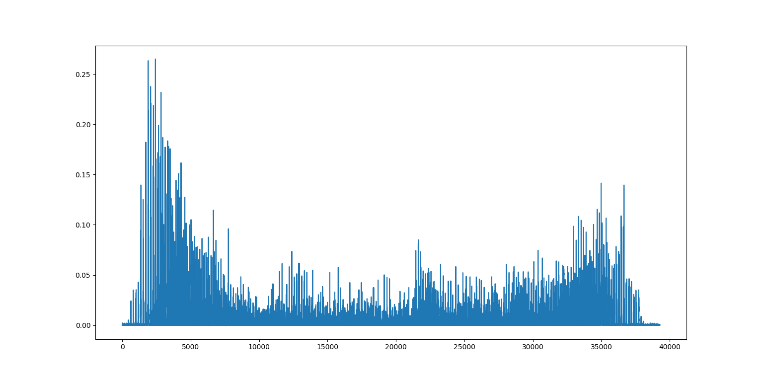
Assumed variance:

1. The Relative Root Mean Square Error (RRMSE) between the denoised image and noiseless image is .
2. Optimal Parameters
   1. (Beta, Gamma) : (
   2. For (, RRMSE: 0.051
   3. For (, RRMSE: 0.046
   4. For (, RRMSE: 0.046
   5. For (, RRMSE: 0.048
3. Denoised Image
   1. Top Left: Noiseless Image
   2. Top Right: Noisy Image
   3. Bottom Left: Denoised Image
   4. Bottom Right: Difference between Denoised and Noiseless Image



1. Plot of objective function vs iteration

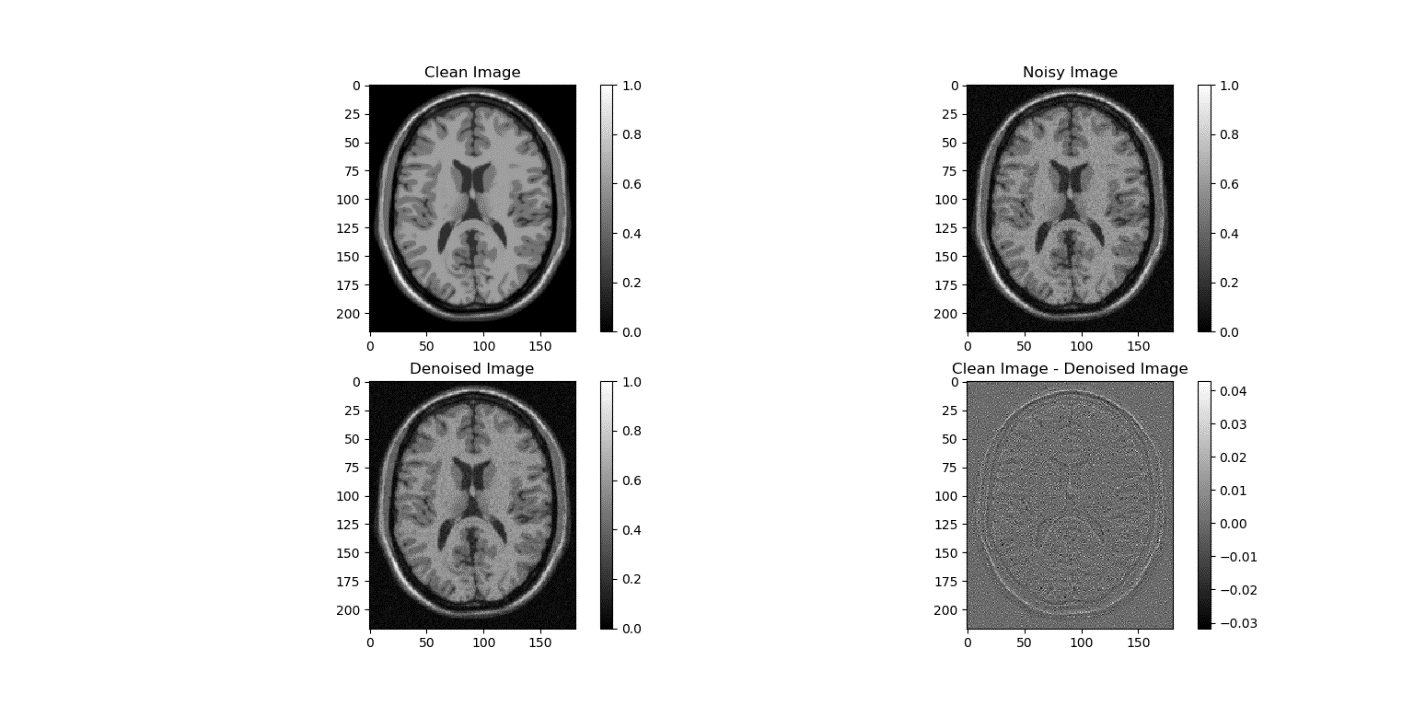
This is after updating every pixel, 1 run



## Noise Level: Medium

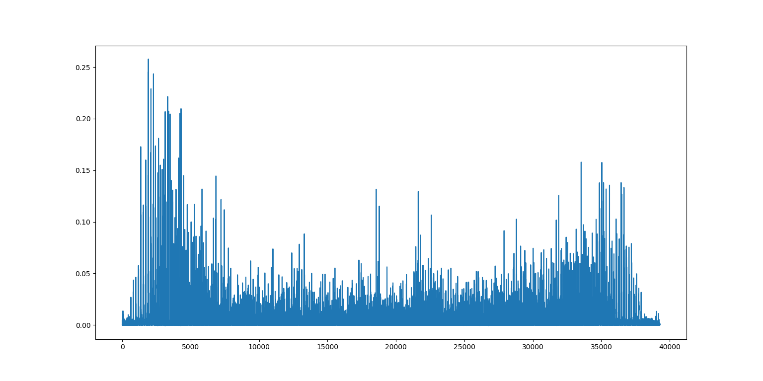
Assumed variance:

1. The Relative Root Mean Square Error (RRMSE) between the denoised image and noiseless image is .
2. Optimal Parameters
   1. (Beta, Gamma) : (
   2. For (, RRMSE: 0.121
   3. For (, RRMSE: 0.117
   4. For (, RRMSE: 0.118
   5. For (, RRMSE: 0.118
3. Denoised Image
   1. Top Left: Noiseless Image
   2. Top Right: Noisy Image
   3. Bottom Left: Denoised Image
   4. Bottom Right: Difference between Denoised and Noiseless Image



1. Plot of objective function vs iteration

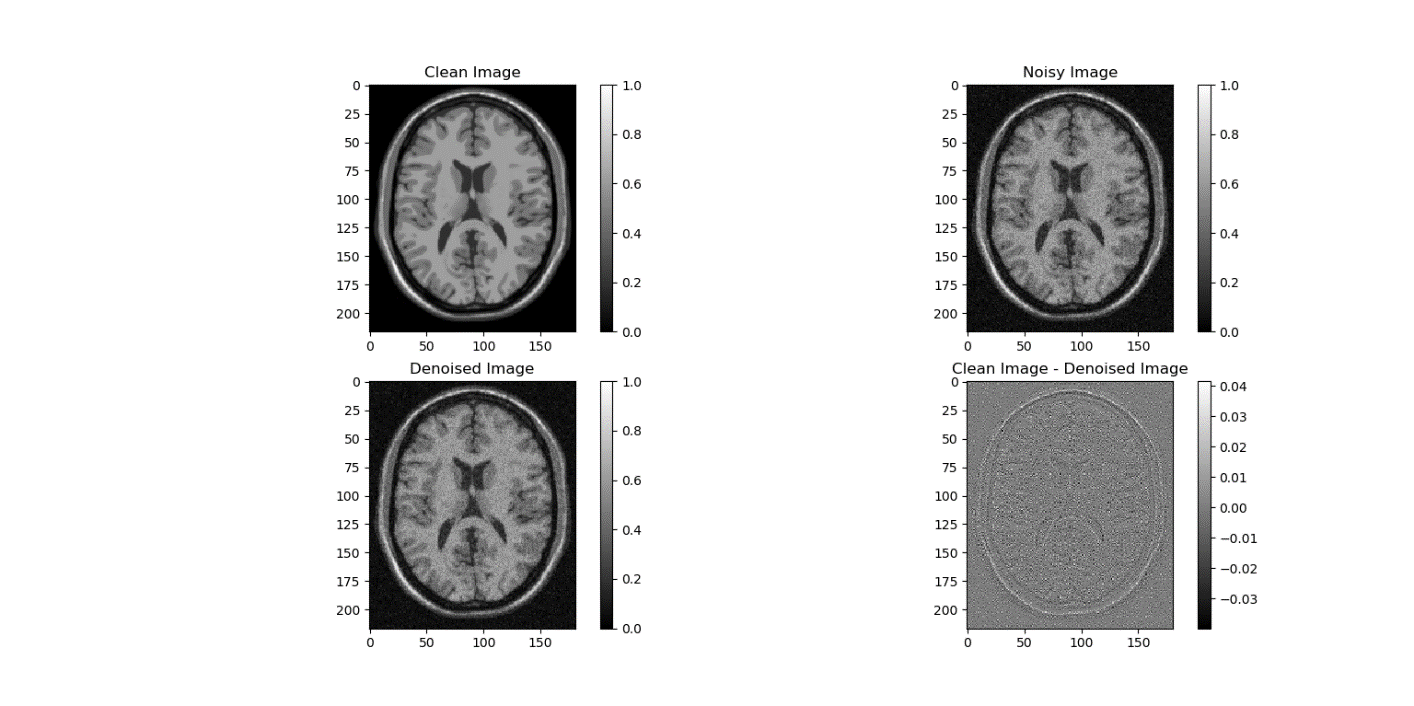
This is after updating every pixel, 1 run



## Noise Level: High

Assumed variance:

1. The Relative Root Mean Square Error (RRMSE) between the denoised image and noiseless image is .
2. Optimal Parameters
   1. (Beta, Gamma) : (
   2. For (, RRMSE: 0.138
   3. For (, RRMSE: 0.132
   4. For (, RRMSE: 0.134
   5. For (, RRMSE: 0.134
3. For (, RRMSE: Denoised Image
   1. Top Left: Noiseless Image
   2. Top Right: Noisy Image
   3. Bottom Left: Denoised Image
   4. Bottom Right: Difference between Denoised and Noiseless Image



1. Plot of objective function vs iteration

This is after updating every pixel, 1 run

