Image Preprocessing of Brain Data

Name: Karthick Sivakumar
Professor: Lifang He

Introduction

Magnetic resonance imaging (MRI) is a powerful medical imaging technique used for diagnosing and monitoring diseases. However, MRI images are often corrupted by noise, which can impact the accuracy and reliability of image analysis. To this end, various preprocessing techniques were tried and tested in this project, including Gaussian filtering, median filtering, and sharpening. These techniques are commonly used in medical image processing and have demonstrated successful results in improving image quality.

The aim was to investigate how these techniques could be used to denoise and enhance the quality of MRI images from the BrainWeb Data Set, which included T1, PD, and T2 data with 1mm, 3%, and 9% of noise, and 0% of intensity nonuniformity. Experiment results were discussed and the implications of the findings were explored to understand the possibility of improving preprocessing techniques for MRI images.

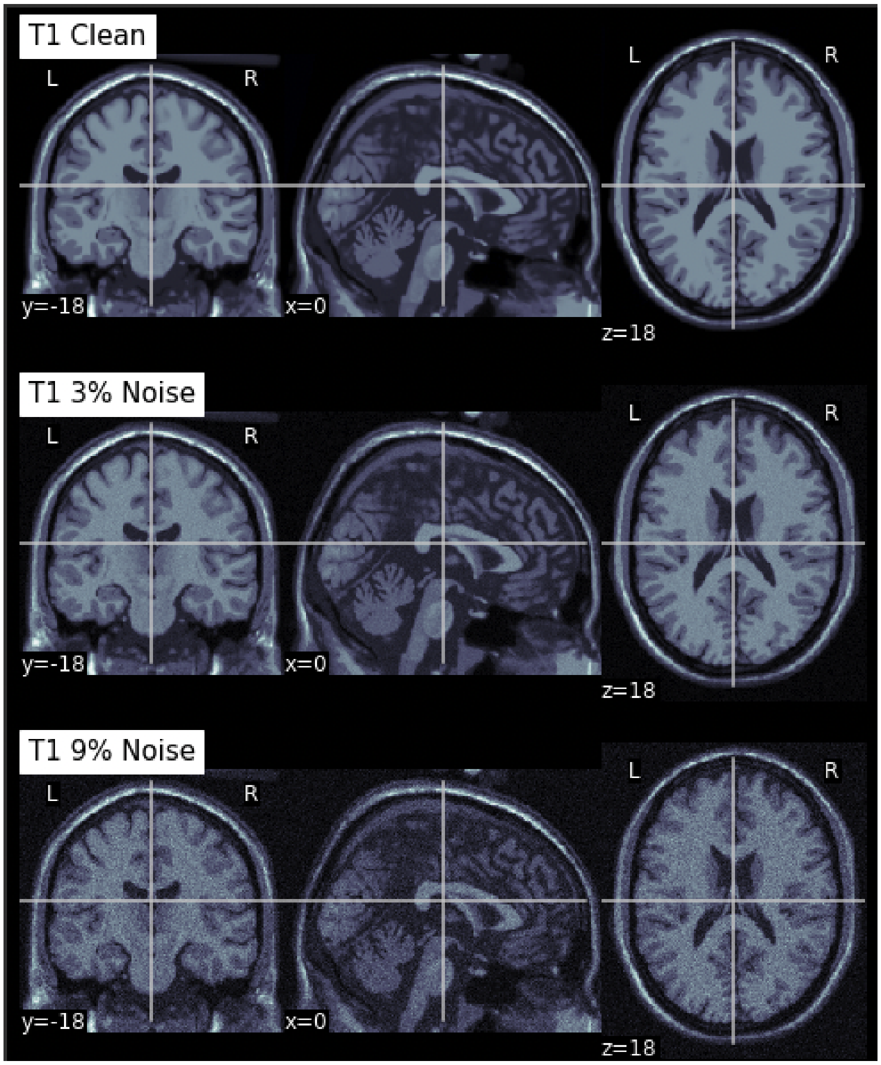
This report provides a summary of my findings. I have discovered that a combination of Gaussian filtering, median filtering, and sharpening can successfully reduce the noise levels present in the MRI images, while also improving the overall contrast of the images.

T1 Modality

The T1 modality of magnetic resonance imaging (MRI) is based on the principle that different tissues in the brain have different fat content and water content. Specifically, T1-weighted images highlight regions with higher fat content, such as white matter, while regions with more water content, such as cerebrospinal fluid (CSF), appear dark. Grey matter, which has a medium fat content, appears as an intermediate shade of grey.

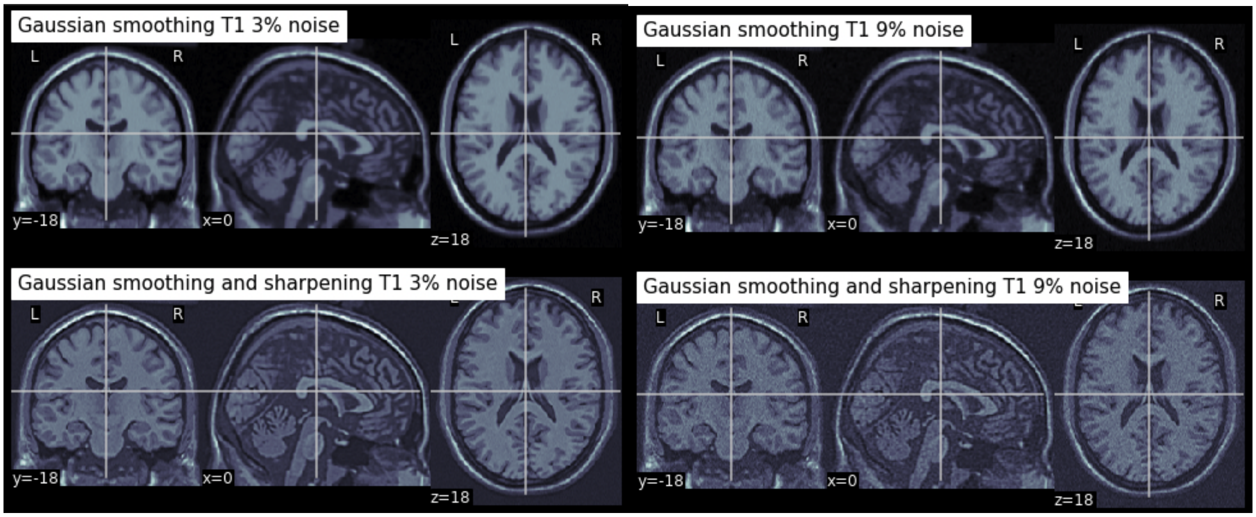
The purpose of this section is to preprocess and denoise T1 MRI images while preserving the edges between the three regions of varying fat content. This is important because the edges between these regions provide valuable information for accurate diagnosis and treatment planning. By removing noise from the images, we can enhance the visibility of these edges and improve the overall quality of the T1 MRI data.

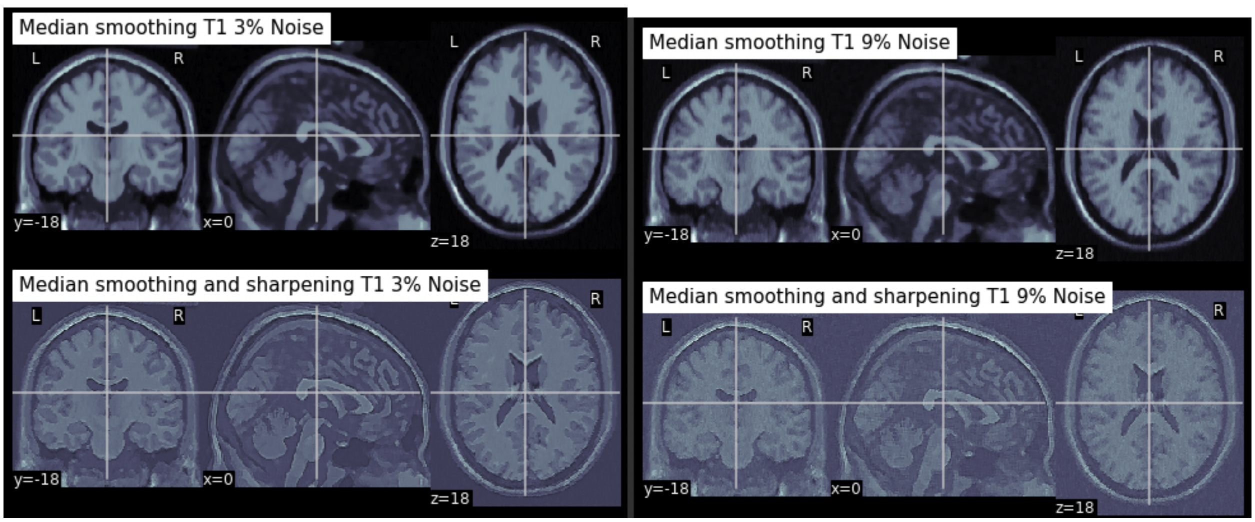
The following is and image of the original clean and noisy data as well as the table of CVs from clean data as well as 3% and 9% noise for T1 modality:



	Clean	3% Noise	9% Noise
CV	1.0686	0.9977	0.8629

From here, I performed Gaussian filtering, Median filtering and Sharpening to improve the results:





Filtering Method	3% Noise	9% Noise
No Filter	0.9977	0.8629
Gaussian	0.9718	0.8230
Gaussian + Sharpening	1.1345	0.9924
Median	0.9783	0.8311
Median + Sharpening	1.2053	1.0463

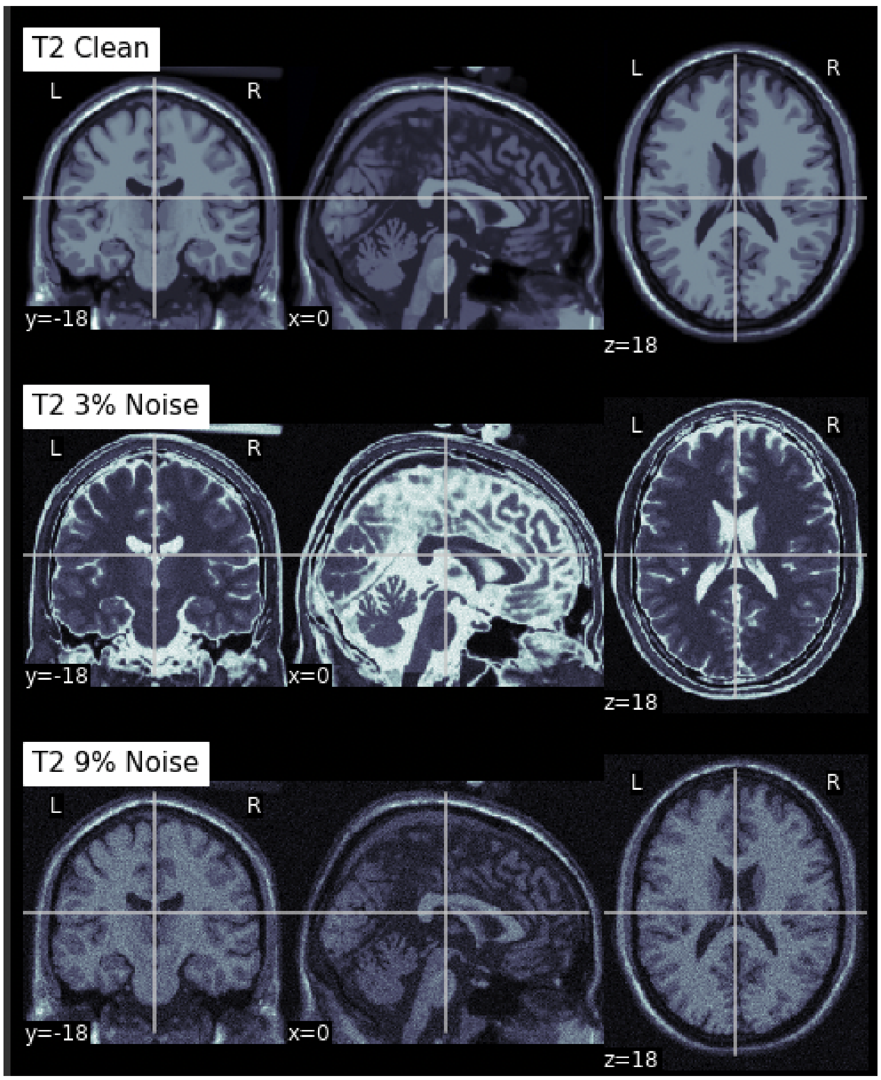
T2 Modality

The T2 modality of magnetic resonance imaging (MRI) is based on a different principle than the T1 modality. While T1-weighted images highlight regions with higher fat content, T2-weighted images highlight regions with high fluid content, such as cerebrospinal fluid (CSF).

This means that CSF appears brighter in T2 images, while regions with less fluid content appear darker.

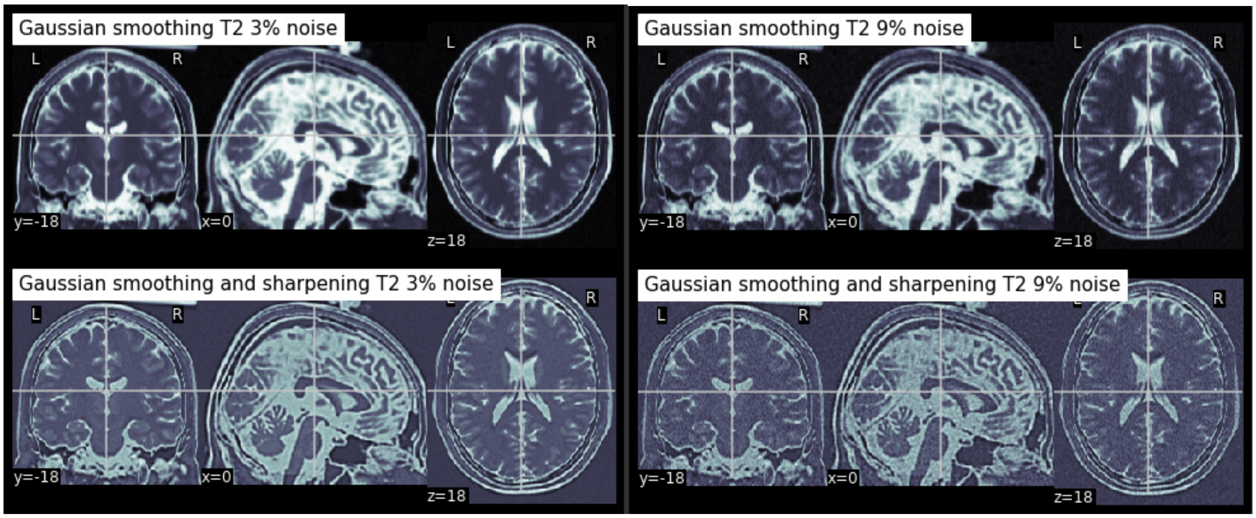
During the preprocessing of noisy T2 MRI images, I noticed that noise can cause a reduction in the brightness of highlighted CSF regions. The filtering methods that I used, which include a combination of Gaussian filtering and sharpening, as well as median filtering and sharpening. The goal of these filtering techniques is to remove noise while preserving the important features of the image, such as the contrast between regions of different fluid content.

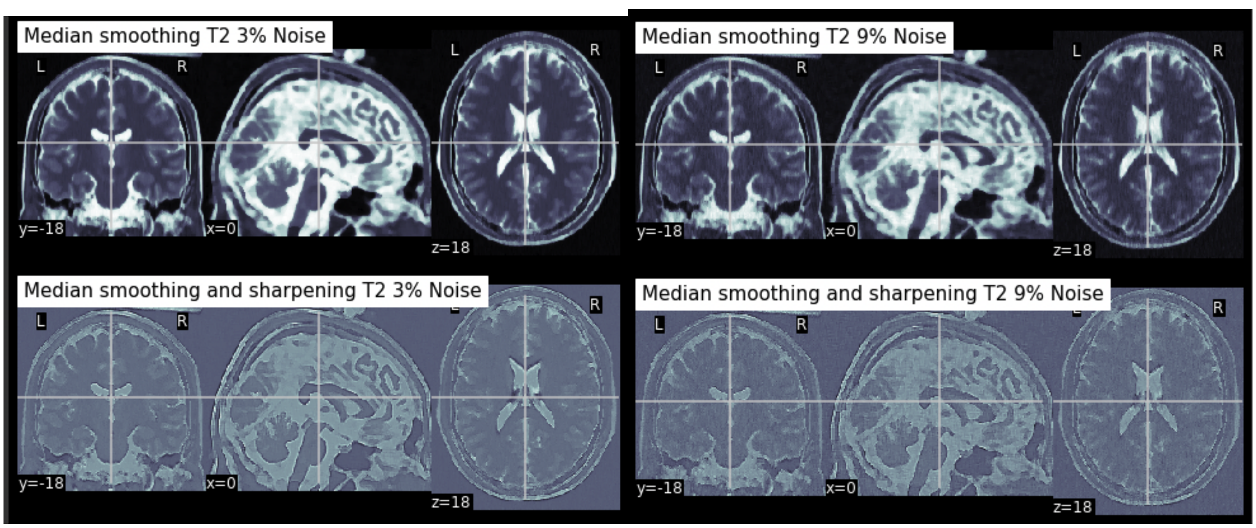
The following is and image of the original clean and noisy data as well as the table of CVs from clean data as well as 3% and 9% noise for T2 modality:



	Clean	3% Noise	9% Noise
CV	1.0429	0.9592	0.8047

From here, I performed Gaussian filtering, Median filtering and Sharpening to improve the results:





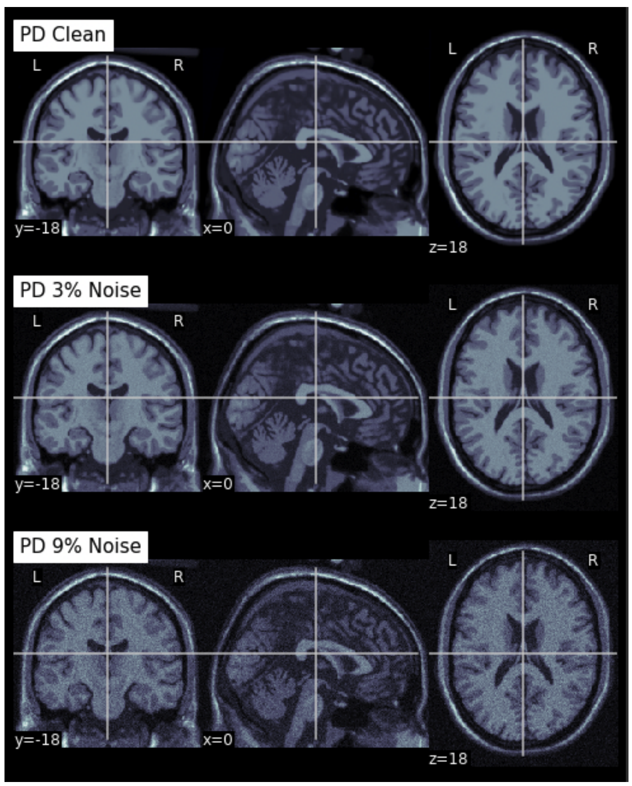
Filtering Method	3% Noise	9% Noise
No Filter	0.9592	0.8047
Gaussian	0.8905	0.7120
Gaussian + Sharpening	1.2517	1.0660
Median	0.9138	0.7235
Median + Sharpening	1.4118	1.1462

PD Modality

Proton density (PD) modality of magnetic resonance imaging (MRI) is a type of weighted image that gives insight into the concentration of hydrogen nuclei (protons) in different tissues of the brain. The PD-weighted images are highly useful in visualizing structures that have high levels of water and protons, such as white matter and grey matter. Both white and grey matter appear similar in brightness in PD-weighted images, while cerebrospinal fluid (CSF) appears dark.

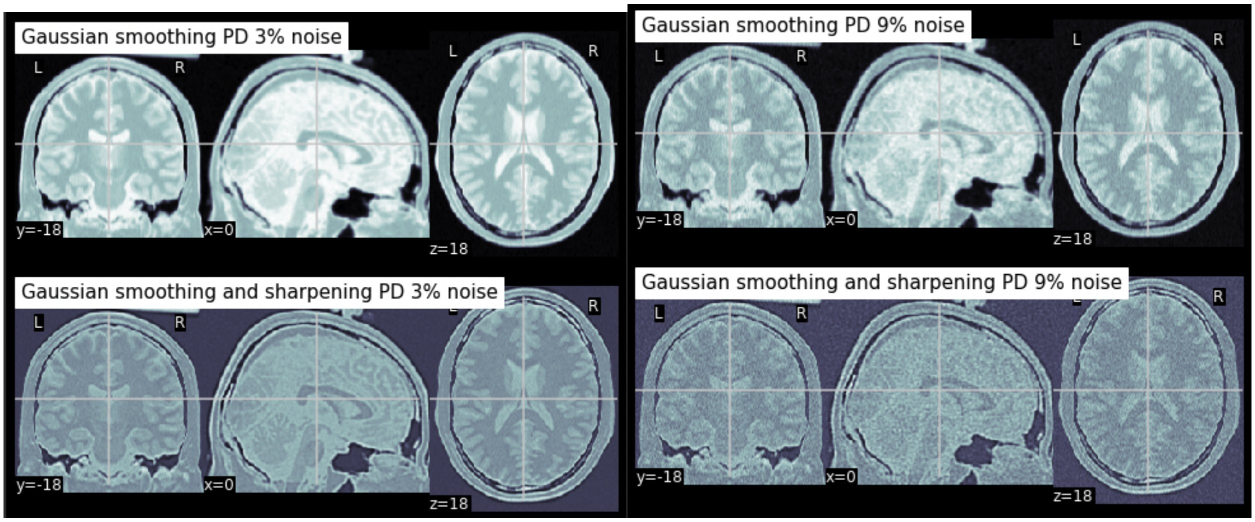
PD-weighted images are routinely used in conjunction with T1-weighted and T2-weighted images, providing an in-depth view of the brain's anatomy and any existing pathologies. In addition to this, the PD-weighted images are also used to monitor the progress of certain diseases and to assess the effectiveness of certain treatments.

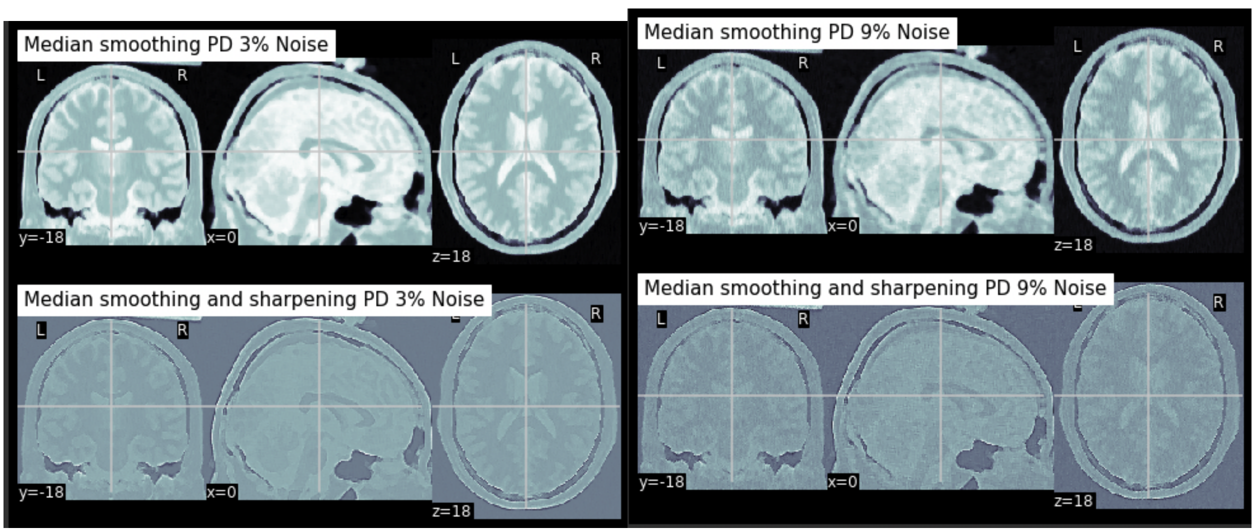
The following is and image of the original clean and noisy data as well as the table of CVs from clean data as well as 3% and 9% noise for PD modality:



	Clean	3% Noise	9% Noise
CV	0.8775	0.8268	0.7236

From here, I performed Gaussian filtering, Median filtering and Sharpening to improve the results:





Filtering Method	3% Noise	9% Noise
No Filter	0.8268	0.7236
Gaussian	0.8074	0.6915
Gaussian + Sharpening	0.9211	0.8138
Median	0.8167	0.7026
Median + Sharpening	1.0222	0.8878

Conclusion

In terms of CV, median smoothing appears to get CV values closer to the clean image than Gaussian smoothing. However, I found that median smoothing tends to wash out the images a lot after smoothing and sharpening, sacrificing visual clarity for CV values. For images like PD where edges are not as discrete, the end result becomes very opaque; I think Gaussian smoothing and sharpening produced a better processing result based on visual clarity and brightness for the PD modality. It maintains a very faint edge, although in 9% noise, the edge was barely visible in the original image. Combining smoothing to remove noise in the background and then sharpening to regain the smoothed edges appears to be a very good way to preprocess images.

I found that the T1 image was most variable overall, except for the instance in T2 when using median filtering and sharpening for 3% which resulted in a CV of 1.4118. The PD actually had the least variability. I think this is because of the very distinct brightness for the different tissue regions in T1 and T2. The more discrete the regions and, consequently, histogram groupings are, the higher the CV. PD had the least discrete regions and so it had the lowest CV.

Using CV as a metric for evaluating the performance of different image processing methods is important because it provides a quantitative measure of the quality of the processed image compared to the original image. It takes into account both the amount of noise reduction achieved and the preservation of image features, such as edges and contrast. While visual inspection is also important, CV can provide a more objective evaluation of image quality, especially when comparing different methods or processing parameters.