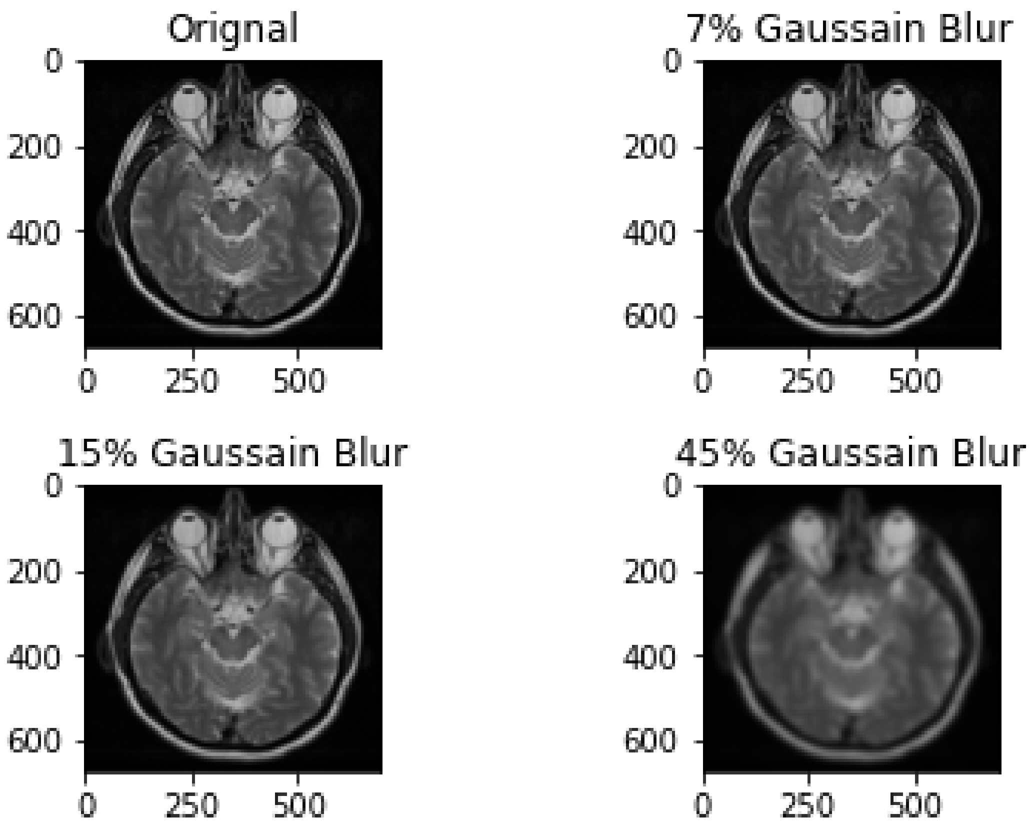
Medical Image Filters:

Different Types of Noise:

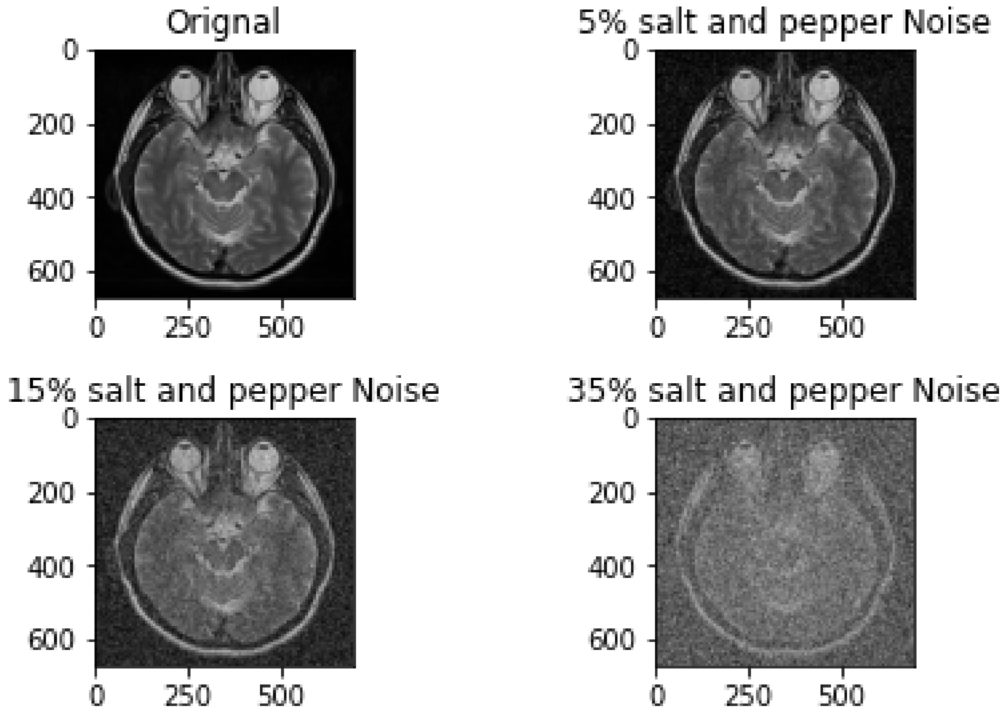
Gaussian Noise:

Gaussian Noise is a statistical noise having a probability density function equal to normal distribution, also known as Gaussian Distribution. Random Gaussian function is added to Image function to generate this noise. It is also called as electronic noise because it arises in amplifiers or detectors. Source: thermal vibration of atoms and discrete nature of radiation of warm objects. The magnitude of Gaussian Noise depends on the Standard Deviation(sigma). Noise Magnitude is directly proportional to the sigma value. (these figures with filters to corresponding g_1, g_2, g_3) *



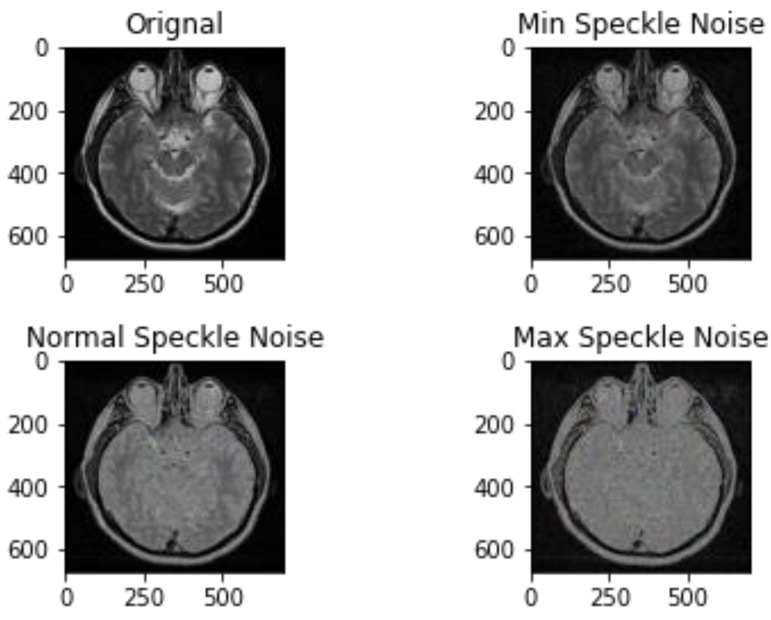
Salt and Pepper Noise:

Salt and Pepper noise is added to an image by addition of both random bright (with 255-pixel value) and random dark (with 0-pixel value) all over the image. This model is also known as data drop noise because statistically it drops the original data values. Source: Malfunctioning of camera's sensor cell. (these figures with filters to corresponding sp_1, sp_2, sp_3) *



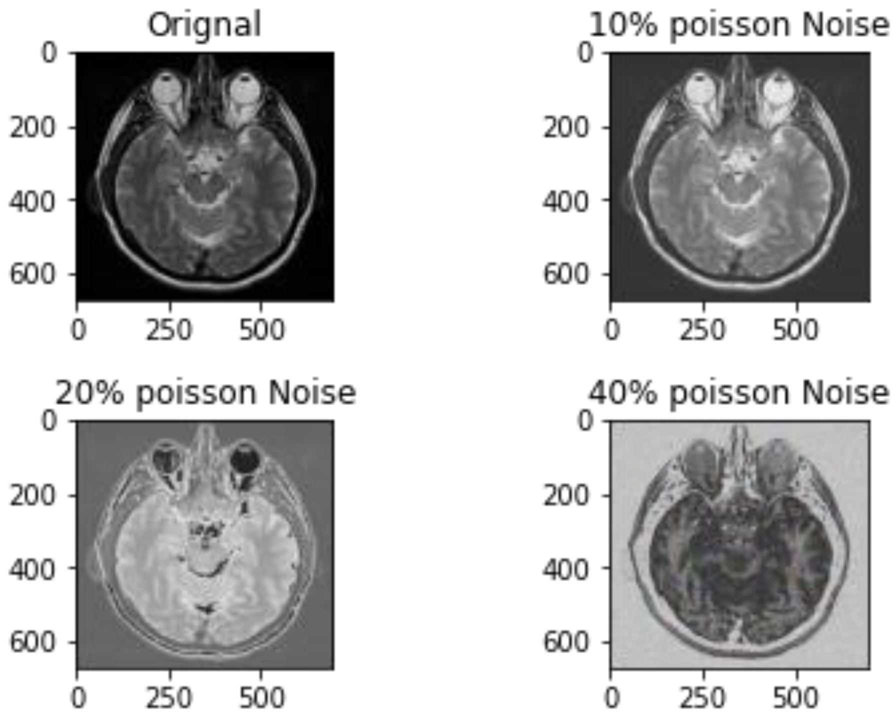
Speckle Noise:

A fundamental problem in optical and digital holography is the presence of speckle noise in the image reconstruction process. Speckle is a granular noise that inherently exists in an image and degrades its quality. Speckle noise can be generated by multiplying random pixel values with different pixels of an image. (these figures with filters to corresponding s_1, s_2, s_3) *



Poisson Noise:

The appearance of this noise is seen due to the statistical nature of electromagnetic waves such as x-rays, visible lights and gamma rays. The x-ray and gamma ray sources emitted number of photons per unit time. These rays are injected in patient's body from its source, in medical x rays and gamma rays imaging systems. These sources are having random fluctuation of photons. Result gathered image has spatial and temporal randomness. This noise is also called as quantum (photon) noise or shot noise. (these figures with filters to corresponding p_1, p_2, p_3) *



Filters

Some different types of Filters are:

Min Filter

The transformation replaces the central pixel with the darkest one in the running window. For example, if you have text that is lightly printed, the minimum filter makes letters thicker.

Max Filter

The maximum and minimum filters are shift-invariant. Whereas the minimum filter replaces the central pixel with the darkest one in the running window, the maximum filter replaces it with the lightest one. For example, if you have a text string drawn with a thick pen, you can make the sign skinnier.

Adaptive Weiner Filter (Freq Domain)

Adaptive Wiener Filter (AWF) is considering frequency domain filter. The adaptive Wiener filter changes its behaviour based on the statistical characteristics of the MR image inside the filter region, which is defined by the maximum rectangular window. Adaptive filter performance is commonly superior to non-adaptive counterparts. Mean and variance are two important mathematics measures using which adaptive filters can be designed. The adaptive Wiener filter uses a pixel-wise adaptive Wiener method based on statistics estimated from a local neighbourhood of each pixel. Its function filters the MR image using pixel-wise adaptive Wiener filtering, using neighbourhoods of size M-by-N to estimate the local MR image mean and standard deviation.

Median Filter (Nonlinear spatial domain)

The median filter is a very popular image transformation which allows the preserving of edges while removing noise. Just like in morphological image processing, the median filter processes the image in the running window with a specified radius, and the transformation makes the target pixel luminosity equal to the mean value in the running window. This filter works well for removing noise, especially impulse noise

Wavelet Domain Filter

Wavelet denoising relies on the wavelet representation of the image. Gaussian noise tends to be represented by small values in the wavelet domain and can be removed by setting coefficients below a given threshold to zero (hard thresholding) or shrinking all coefficients toward zero by a given amount (soft thresholding).

Adaptive Median Filter

The adaptive Median filter executes spatial processing to determine which pixels in an MR image have been affected by noise. The Adaptive Median Filter classifies pixels as noise by comparison each pixel in the MR image to its surrounding neighbour pixels. The size of the neighbourhood window is adjustable, as well as the threshold for the comparison. A pixel that is different from a majority of its neighbours, as well as being not structurally aligned with those pixels to which it is similar, is labelled as noisy pixel. These noisy pixels are then exchange by the median value of the pixels in the neighbourhood that have passed the noise labelling test. Adaptive median filter changes the size of the neighbourhood window through operation. But, in classic median filter; the neighbourhood window is constant through the operation. For that, the standard median filter does not perform well when the impulse noise density is high, while the adaptive median filter can better handle these noises. Also, the adaptive median filter preserves MR image details such as edges and smooth non-impulsive noise, while the standard median filter does not.

Arithmetic Mean Filter

Replaces the central pixel value with the average of all the values in the window.

Bilateral Filter

A bilateral filter is a non-linear, edge-preserving, and noise-reducing smoothing filter for images. It replaces the intensity of each pixel with a weighted average of intensity values from nearby pixels. This weight can be based on a Gaussian distribution. Crucially, the weights depend not only on Euclidean distance of pixels, but also on the radiometric differences (e.g., range differences, such as color intensity, depth distance, etc.). This preserves sharp edges.

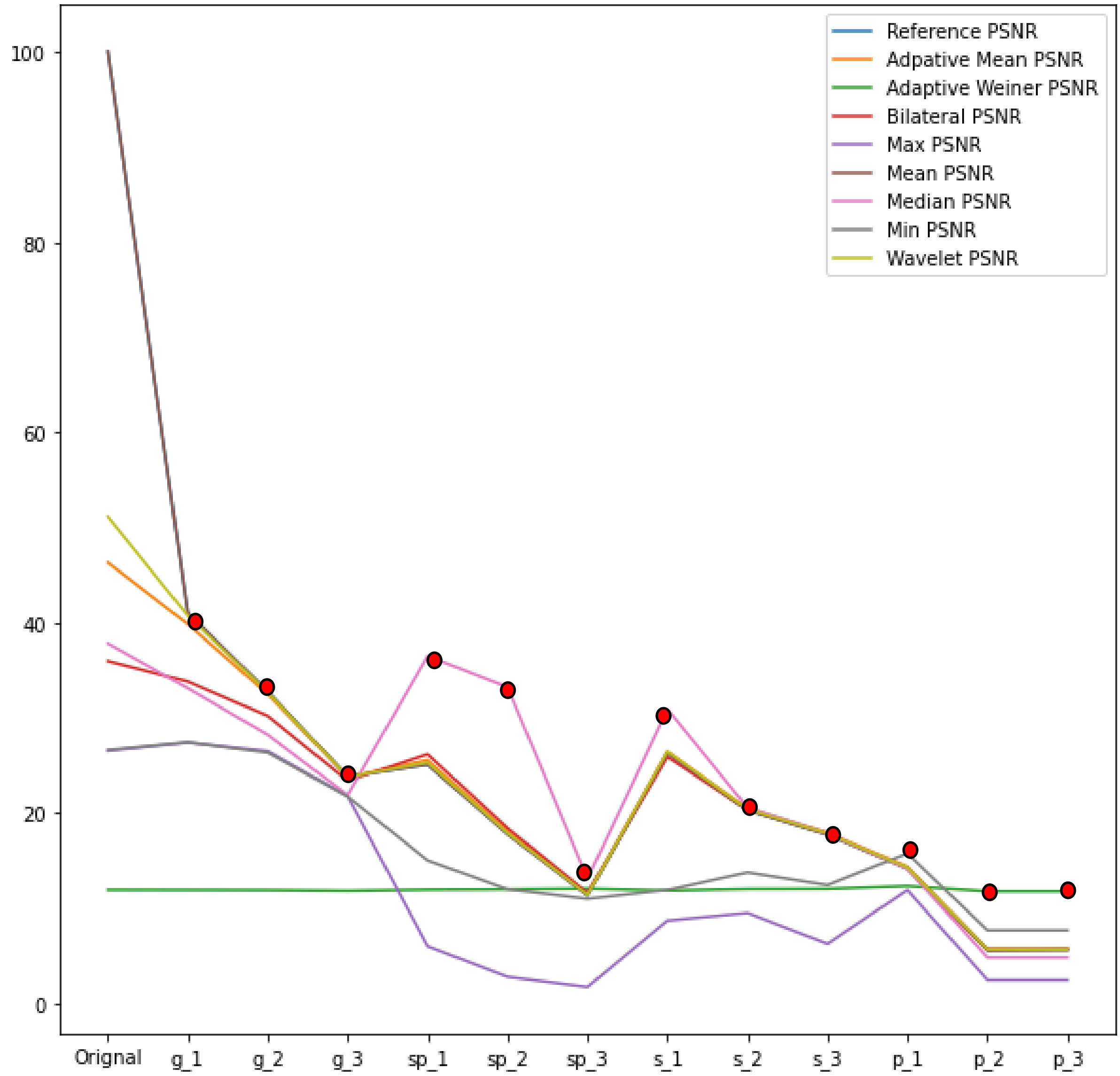
Noise Adaptive Fuzzy switching median Filter (NAFSM)

Speckle Reducing Diffusion Filter (SRAD)

These are combo filters.

PSNR of the filters to the original image.

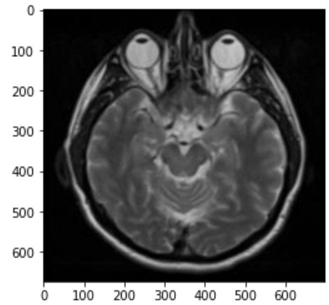
Here the value infinite (the situation for the perfect similarity) was converted to 100, to make the scale easier to read. In the below figure red dots were placed at the maximum values against the appropriate filter.



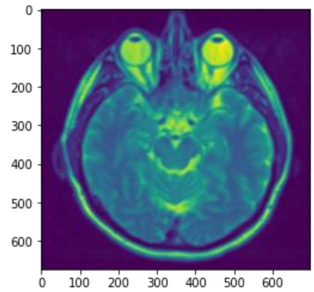
Based on the figure it can be concluded that mean filter performed well against the low level of the gaussian noise, but wavelet filter produced better results as the level of gaussian noise increased. In the subsequent noise in the form of salt and pepper and speckle noise median filter performed consistently well compared to all other filters. Min filter produced the maximum PSNR (peak signal to noise ratio) at low levels of poison noise, but adaptive wiener filter tends to perform well in the case of poison noise.

Table of reconstructed images with the best results according to the PSNR graph.

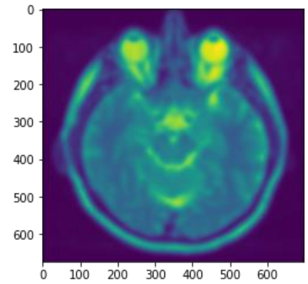
g_1 reconstructed Mean filter



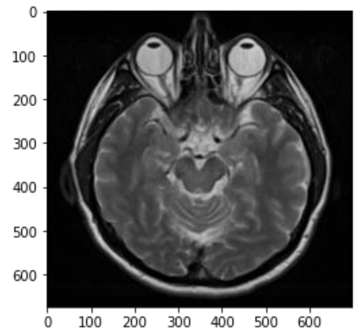
g_2 reconstructed Wavelet Filter



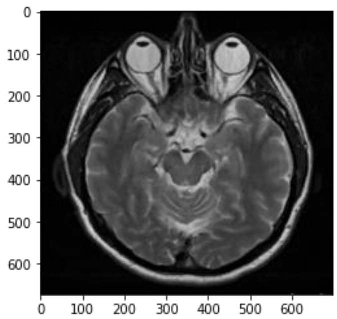
g_3 reconstructed Wavelet Filter



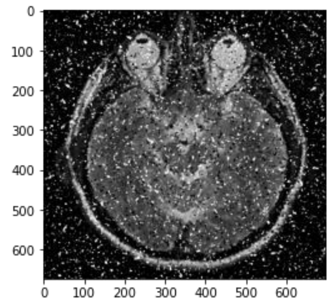
sp_1 reconstructed Median filter



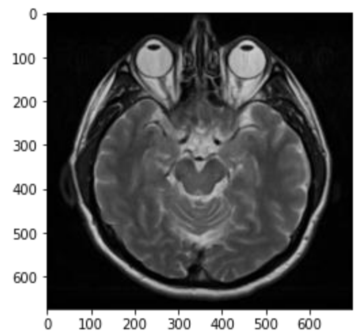
sp_2 reconstructed Median Filter



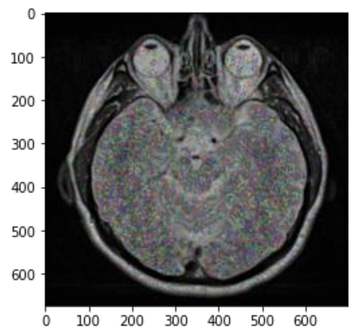
sp_3 reconstructed Median Filter



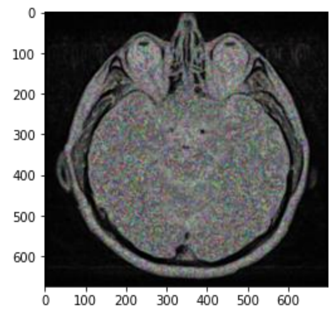
s_1 reconstructed Median filter

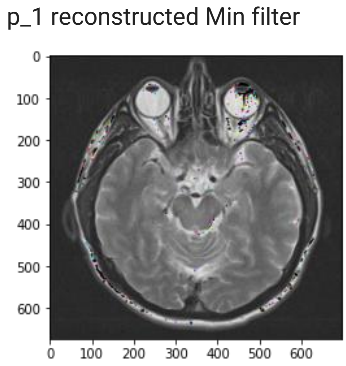


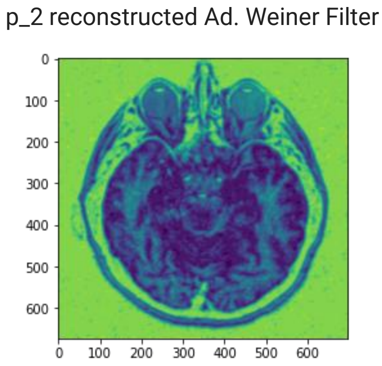
s_2 reconstructed Median Filter

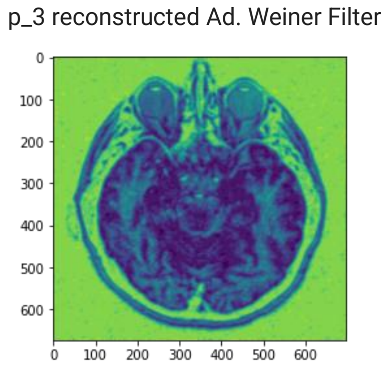


s_3 reconstructed Median Filter




p_1 reconstructed Min filter
0
100
200
300
400
500
600
0 100 200 300 400 500 600


p_2 reconstructed Ad. Weiner Filter
0
100
200
300
400
500
600
0 100 200 300 400 500 600


p_3 reconstructed Ad. Weiner Filter
0
100
200
300
400
500
600
0 100 200 300 400 500 600