EE 331 Probability and Random Processes
Assignment 4
Roll No: 18110026
Submission: 18/11/20

Noise removal in images has applications in various fields, like in MRI, space applications, etc. In the given assignment two techniques for noise removal are compared: **Non-Local Means** and **Gaussian Noise Removal**.

In the Gaussian noise removal technique, the noisy image is convolved with a 2D Gaussian kernel with mean zero, and a specified variance. This technique is also referred to as Gaussian Blur. The Gaussian filter acts as a low pass filter because the Fourier Transform of a Gaussian function results in a Gaussian function only. Therefore, if mean is taken as 0, the pass frequency depends on the variance. However, apart from removing noise, it blurs the edges also in images, as edges represent high-frequency components (suddenly changing colour).

The other technique discussed is the Non-Local Means (NLM) technique, a more robust approach to removing noise. In the NLM technique, each pixel is represented as a weighted function of all other pixels. Higher weight is given to pixel with similar background colour intensity. Along with this, the pixels in the near neighbourhood of the pixel under consideration has higher weights as they are near. This is computed using the weighted Euclidean distance technique. Intuitively, still, the pixels near with same colour intensity are much likely to contribute to the same object in the image. Therefore, weights for very far off pixels with the same colour intensity are almost zero. Hence in the neighbourhood of the pixel, a search window (like a patch of image) is created and analysed, as the weights will be of significant value in this region only. Also: $\sum w_{i,j}$ for all pixel ***i***, with contributing pixels ***j,*** is **1**. The weights have a gaussian distribution with respect to distance.

The given code for assignment is in python and similar approach as the author has been used. For fast computation, the moving average method is used, In the moving average method, pixel intensity difference is computed in the search window size, and in a similar fashion, weights are also computed.

For adding Gaussian weights, the variance is taken as 0.05, and for salt pepper noise the threshold is taken as 4.

MSE PNR Values For Denoised Images

MSE refers to Mean Square Error is computed as the mean of the squared difference between the ground truth and the denoised image. It depicts on average how much a image deviates with the original image. While PSNR (Peak Signal to Noise ratio) is the 20 times log of peak signal to the MSE. For an image, the peak possible pixel value is 255. Hence:

MSE = Mean((Ground truth - Denoised Image).^2)
PSNR = 20log (255/sqrt(MSE))

The following value for some example images are shown below:

	Gaussian Noise Removal				Non Local Means Filtering			
	Gaussian Noise		Salt Pepper Noise		Gaussian Noise		Salt Pepper Noise	
	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR
1	30.010,	33.358	64.34	30.046	106.88,	27.84	43.93	31.70
2	45.45	31.75	47.22	31.389	59.799	30.36	45.03	31.59

The corresponding images including ground truth, noisy images and denoised images are as follows:

The following examples correspond to Indexed values in the above table:


Colored Ground truth

Gaussian Noise

Salt Pepper Noise

Gaussian Filter Results respectively on the above-added noises.

Denoised Images using NLM filter: Gaussian noise and Salt Pepper noise respectively

Example 2


Ground Truth



Added Gaussian and Salt Pepper Noise



Removed noises with Gaussian Filter

Denoised Images using Non Local Means Filter: Gaussian and Salt Pepper noise

General Observations:

- Gaussian Filter is not able to remove Salt Pepper noise properly, while in other cases it majorly smoothens edges and decreases the sharpness of the image.
- In the case of Non-Local Means, though the edge sharpness is maintained, however minute variations in the colour intensities are totally removed leaving large smooth patches in the image. This may decrease the intricacies of the image.
- The MSE obtained with NL Means filter is higher as it smoothens the patches of an image, while Gaussian filter majorly smoothens the edges. However, the differences can be adjusted by changing various parameter values in the filter. Also, the extent of noise removal largely depends on the noise level. In this case, this level has been kept the same. However, a better analysis would have been obtained by changing the noise levels also.
- Clearly, as MSE increases slightly, PSNR reduces in NL Means Algorithm.
- In general, we can say that the Gaussian filter isn't the best choice for Salt Pepper noise and smoothens the edges. While NL Means Filter removes Salt Pepper noise much effectively, however, smoothens patches of the image.

References:

1) https://ieeexplore.ieee.org/abstract/document/1467423
2) http://www.numerical-tours.com/matlab/denoisingadv_6_nl_means/#32
3) https://quasar.ugent.be/bgoossen/download_nlmeans/
4)