Denoising and Quality Enhancement of CT Scan/X-ray images of Lung disease for Enhanced Diagnosis

Anitha N[1], Rajesh T M[2], Pritee Parwekar[3], Nitheesh Ram Chatradi[4]

[1] Department of CSE, Dayananda Sagar University, Karnataka, India
anithan.res-cse@dsu.edu.in
[2] Department of CSE, Dayananda Sagar University, Karnataka, India
rajesh-cse@dsu.edu.in
[3] Department of CSE, RV College of Engineering, Karnataka, India
nschakradhar.cs21@rvce.edu.in
[4] Department of CSE, RV College of Engineering, Karnataka, India
nitheeshramc.cs21@rvce.edu.in

Abstract. Medical imaging is crucial in a variety of medical fields and at all major levels of health care. Medical imaging is necessary to track the progress of an ongoing illness. Further it plays a pivotal role in assisting the surgeons and physicians in diagnosing the diseases. These days the medical field predominantly depends on scanned images for accurate diagnosis or for research purposes. These images are ingrained with various kinds of noises which are inevitable. Diagnosis of these kinds of images leads to varied perception. For efficient and accurate diagnosis, these images should be denoised with edge-preserving methods. Reducing the noise without losing the content of images is a challenging task. Various techniques are used to suppress the noise with each technique having their own merits and limitations. In this paper we employed various filtering and contrast enhancement techniques to eradicate salt and pepper noise, gaussian noise, uniform noises and enhanced image quality.

Keywords: Image filtering, Salt and pepper noise, Mean and median filters, Histogram equalization, Contrast Limited Adaptive Histogram Equalization (CLAHE)

1 Introduction

Medical image processing includes the use and investigation of 3D images of the human body, typically from a Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) scanner, for pathology diagnosis, to direct medical treatments like surgical planning, or for research. Radiologists, engineers, and physicians process medical images to gain a better understanding of the anatomy of either specific individuals or populations.

In a wide range of medical settings and at all significant levels of health care, medical imaging is essential. Diagnostic imaging services are crucial for validating, evaluating, and recording the evolution of various diseases and the effectiveness of treatment. Medical imaging is a pivotal part of the refined outcomes of modern medi- cine. Various types of medical imaging techniques include:

- X-rays
- Magnetic resonance imaging (MRI)
- Ultrasounds
- Endoscopy
- Tactile imaging
- Computerized tomography (CT scan)

Efficiency of diagnosis based on scanned images predominantly depends on acquisition of image, processing of image and display. Medical images are prone to different noises which are assimilated during acquisition of images. The image may be blurred or gets different noises due to various reasons it may be due to movements of patients such as breathing and heartbeat, or may be due to fluctuations of pixels in the image or due to inappropriate way of operating equipment. This makes images inade- quate for diagnosis. Use of various filtering and contrast enhancement techniques al- lows us to remove noise and enhance the quality of pre-processed images.

A sequential representation of steps followed in diagnosis are shown in the below Fig. 1. It all begins with the act of acquiring an image from a source using hard- ware systems such as sensors, encoders, cameras etc... which are the first two steps of the process. This is then followed by image processing which involves converting the image into digital form. It allows us to perform different techniques like enhancing color, calculate area of cells, restore images and smoothing of images. Finally display of the processed image is done in a suitable reading environment for diagnosis. Inherent noises vary based on the imaging technology that is used for acquisition of image.

Se- lection of appropriate filtering techniques is required to remove the noise and smoothenthe image.

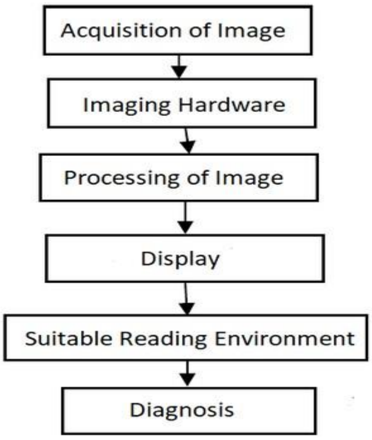


Fig. 1. Steps in diagnosis of disease

2 Literature Review

In paper [1], common filtering and contrast enhancement methods for CT scan noise reduction, image smoothing, and contrast enhancement are covered. After receiving the experiment's findings, they visually inspected them and discovered that the median fil- ter performed better at smoothing out the Gaussian noise. Median filter outperforms other methods when it comes to measuring image clarity. While contrast stretching out- performs other techniques in terms of image quality measurements and visual inspec- tion of contrast enhancement techniques, AHE technique enhances the low contrast CT scan image and retains image details for diagnosis. As a result, the median filter works better than other filtering techniques. According to CT brain images, adaptive histo- gram equalization and contrast stretching work well in contrast enhancing technique.

Paper [2], investigates the application of transfer learning architectures for COVID-19 detection using CT lung imaging. The results of this study point to transfer learning-based frameworks as an alternative to the modern approaches to determining whether the virus is present in a patient. On a SARS-CoV-2 dataset, the model with the best performance, the VGG-19 applied with Contrast Limited Adaptive Histogram Equalisation, had accuracy, and recall of 95.75% and 97.13%, respectively.

Paper [3], demonstrate how to increase the sensitivity of chest X-rays using the PACE (Pipeline for Advanced Contrast Enhancement) nonlinear post-processing tool, which effectively combines Contrast Limited Adaptive Histogram Equalisation (CLAHE) and Fast and Adaptive Bidimensional Empirical Mode Decomposition (FABEMD). According to three commonly used metrics—the contrast improvement index, entropy, and measure of enhancement—the results demonstrate an improvementin visual contrast.

In Paper [4], the original grey scale or V-image is enhanced using un- sharp masking, and then an Adaptive histogram equalization and exponential transformation. The output image is color if the original image is grayscale. The fresh grayscale picture. If the input picture is colored, the method combines the new V- image with the older H and S images, which are left alone, to produce a new HSV image. The enhanced color picture was produced using the RGB is changed back to new HSV. The suggested en- hancement process has been shown to work well with a variety of medical images, including X-ray, MRI, and CT images, and it does not require the user to define or modify settings. The new technique outperformed other traditional approaches like HE, CLAHE, a wavelet-based methodology, and a fuzzy-based strategy.

In paper [5], the contrast of image fusion techniques for medical images is presented. Based on entropy analysis, it is suggested that the adaptive fusion algorithm be implemented. Spatial domain techniques like CLAHE are being implemented to cre- ate a multi-focused image collection, from a single medical image. The efficiency and proper working of the three enhancement techniques i.e. based on entropy analysis, pixel level minima, maxima, and averaging are compared.

3 Various types of Noises

Noise refers to any unwanted variation or distortion in an image that can arise due to various factors, such as the environment, equipment, and algorithms used in image ac- quisition and processing. Noise can make it difficult to extract meaningful information from an image, and it can also affect the accuracy and reliability of image analysis algorithms. In this answer, we will explore some common types of noise in image pro- cessing and some methods for reducing or removing noise.

Common types of Noise in image processing and Filtering Techniques are

- **Gaussian Noise**
- **Salt and Pepper Noise**
- **Uniform Noise**

3.1 Gaussian Noise

Gaussian noise is commonly encountered in image processing. It is caused by random variation of intensities of pixels in an image, and it has a probability distribution that follows a Gaussian or normal distribution. Gaussian noise can be introduced into an image during image acquisition or it can result from image processing operations. The residence of Gaussian noise in an image has a significant effect on the quality and accuracy of the image analysis. Gaussian noise can reduce the contrast and sharpness of an image, and it can also introduce false features and distortions. To reduce or remove Gaussian noise from an image, various filtering techniques can be applied. These techniques are based on integrating the image with a filter kernel that is designedto smooth the image while preserving its important features.

Some common filtering techniques for reducing Gaussian noise are:
Gaussian filtering: This is a linear filtering technique that applies a Gaussian blur tothe image. The filter kernel used in this technique has a Gaussian shape, which meansthat it assigns additional weight to the pixels at the center of the kernel and less weightto the pixels on the edges. Gaussian filtering is effective in reducing Gaussian noisewhile preserving the crucial features of an image.
Median filtering: This is a nonlinear filtering technique that replaces every pixel with the median value among the neighboring pixels. This technique has a notable effective on reducing salt and pepper noise as well as Gaussian noise.

The formula for adding Gaussian noise to a signal:

$$y = x + N(0, \sigma) \tag{1}$$

In the above equation 1, a noisy signal y is obtained by adding an original signal x and a Gaussian noise with mean 0 and standard deviation σ. Fig. 2 represents the CT scan image of Covid patient before and after addition of Gaussian noise.

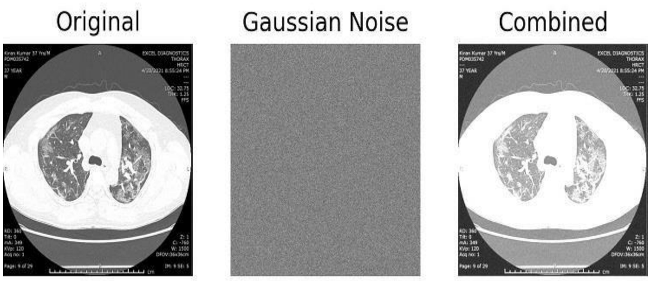


Fig. 2. CT scan image of Covid patient before and after addition of Gaussian noise

3.2 Salt and Pepper noise

Salt and pepper noise is one of those noise that is commonly encountered in image processing. It is caused by random variations in the intensities of pixels in an image, and it appears in white and black dots in the image. This sort of noise is referred as salt and pepper noise because it looks like someone has sprinkled salt and pepper on the image. Salt and pepper noise can be introduced into an image during image acquisition or it can result from image processing operations.The residence of salt and pepper noise in an image can significantly affect the quality and accuracy of image analysis algo- rithms. Salt and pepper noise could reduce the contrast and sharpness of an image, and it can also introduce false features and distortions.

Some common filtering techniques for reducing salt and pepper noise are:

Median filtering: This is a nonlinear filtering technique that replaces each pixel in the image with the median value of the neighboring pixels. Median filtering is very effec- tive in reducing salt and pepper noise while preserving the important features of the image.

Adaptive median filtering: This is a variant of median filtering that adapts the size of the filter window based on the local statistics of the image. Adaptive median filtering is effective in reducing salt and pepper noise while protecting the important features ofthe image.

Bilateral filtering: This is a nonlinear filtering technique that preserves edges in an image while reducing noise. Bilateral filtering is effective in reducing salt and pepper noise while protecting the important features of the image.

In conclusion, Salt and pepper noise is a common type of noise in image pro- cessing which can significantly affect the quality and accuracy of image analysis algo- rithms. To reduce or take out salt and pepper noise from an image, various filtering techniques can be applied, including median filtering, adaptive median filtering, and bilateral filtering. The choice of filtering technique will depend upon the specific char- acteristics of noise and image. Fig. 3 represents the CT scan image of Covid patient before and after addition of Salt and pepper noise.

The formula for salt and pepper noise can be expressed as:

$$I(i,j) = \begin{cases} z(i,j) & \text{if } q(i,j) < Pa \\ w(i,j) & \text{if } q(i,j) > 1 - Pb \\ r(i,j) & \text{otherwise} \end{cases} \quad (2)$$

f

In above equation 2, the noisy image I(i,j) is same as maximum intensity value z(i,j) when uniformly distributed random variable between 0 and 1, q(i,j) is less than the probability of a pixel being affected by salt noise Pa or minimum intensity value w(i,j) if q(i,j) is greater than (1- the probability of a pixel being affected by pepper noise), or original image r(i,j) otherwise.

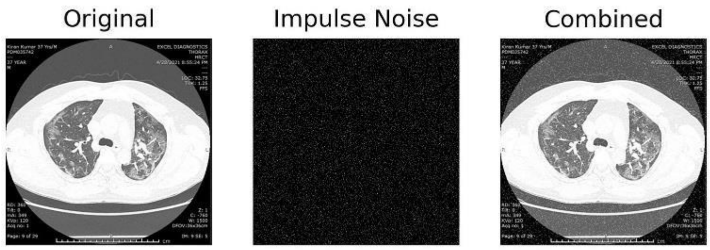


Fig. 3. CT scan image of Covid patient before and after addition of salt and peppernoise

3.3 Uniform Noise

Uniform noise is one of the noises that can occur in digital images. It is characterized by having a constant intensity level across the image with some random variations. Uniform noise can be modelled mathematically as a random variable ‘u’ that is uni- formly distributed between two values a and b, where b is the maximum possible value and a is the minimum possible value. The probability density function of ‘u’ is given by:

$$f(u) = \begin{cases} 1/(i-j) & \text{if } i \leq u \leq j \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

In image processing, uniform noise can be added to an image by adding a random value from the uniform distribution to each pixel in the image. The amount of noise added to each pixel can be controlled by adjusting the minimum, maximum values of the uniform distribution. Fig. 4 represents the CT scan image of Covid patient before and after ad- dition of uniform noise. The formula for adding uniform noise to an image can be expressed as:

$$I(i, j) = I(i, j) + U(p, q) \quad (4)$$

In above equation 4, the noisy image I(i, j) is obtained by adding a uniformly distributed random variable between p and q, where p and q are the lower and upper bounds of theuniform distribution, respectively to the original image.

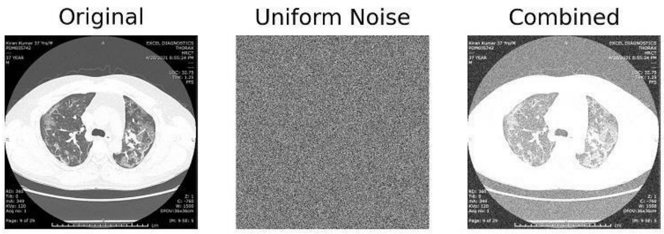


Fig. 4. CT scan image of Covid patient before and after addition of uniform noise

4 Filtering Techniques

Filtering techniques are used for modifying or enhancing an image. Image filtering is very important part for the smoothing process. Also generally, filters are used for blur- ring, noise reducing, sharpening and edge detection of images. Image filters are mainly used to maintain high (smoothing techniques) and low frequencies (image enhance- ment, edge detection) in a level. Let us study various filtering techniques.

4.1 Mean Filtering Technique

Mean filtering technique is a filter to reduce the noise and smoothen an image. This technique uses a kernel (a square window) which moves over the image pixel by pixel. Here, intensity value of each pixel is equated to average intensity values of all surround- ing pixels. Similarly, it is repeated for each pixel of the image to obtain an image with averaged intensity values of surrounding pixels. Considering a kernel size of 3*3 the average intensity value is calculated as the sum of intensity value of that pixel and its surrounding 8 pixels divided by 9. A larger kernel size will result in a more smoothed image but may also result in loss of fine details in the original image.

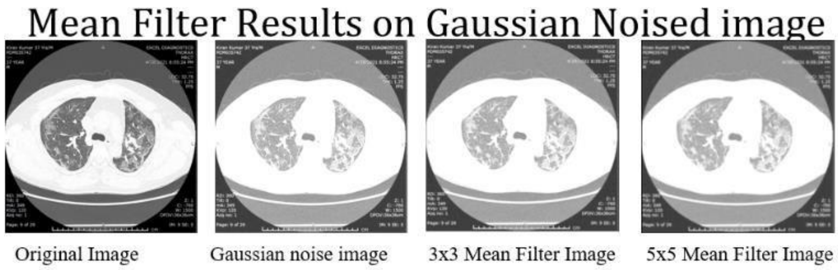


Fig. 5. CT scan image of Covid patient after applying mean filter on a gaussian noised image

Here, Fig. 5 represents the original image, Gaussian noise image, using kernel of a size 3*3 on the noisy image, using kernel of size 5*5 on the noisy image using mean filters.

The mathematical formula for a mean filter of size (2k+1) x(2k+1) applied toa pixel at position (i,j) in an image can be represented as:
Consider, k=-k & l=-k

$$FI(i, j) = (1/((2k+1)^2)) * \Sigma \Sigma \, image(i+k, j+l) \qquad (5)$$

In above equation 5, pixel at position (i, j) in the filtered image FI(i, j) is ob-
tained by taking the average value of all the pixels within a (2k+1)x(2k+1) window centered at the pixel of interest.

4.2 Median Filtering Technique

Median filtering is a non-linear filtering technique widely used to decrease the noise and smoothen images. Here, the complete details of the image are preserved. Here, the intensity value of each pixel in image is equated to median value of all surroundings intensity value of pixels. This is repeated for each pixel in the image to obtain an image with the median intensity value of surrounding pixels. Considering a kernel size of 3*3, the resultant intensity value is equal to the median intensity value of nine pixels. It is widely regarded as an efficient way to remove salt and pepper noise (Noise which results in isolated white and black pixels in image). Hence, this technique allows us to better visualize CT scans.

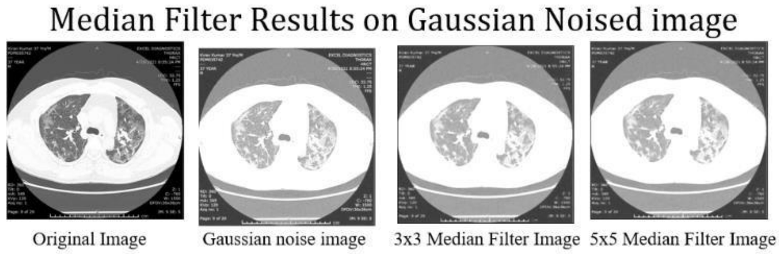


Fig. 6. CT scan image of Covid patient after applying median filter on a gaussian noised image

Here, Fig.6 represents the original image, Gaussian noise image, using kernel of a size 3*3 on the noisy image, using kernel of size 5*5 on the noisy image using median filters.

$$\text{Sorted pixels} = \text{sort}([image(i+k, j+l) \mid -k \le k \le k, -k \le l \le k])$$

$$\text{Filtered image}(i,j) = \text{sorted pixels}((2k+1)^2/2 + 1)$$

In above equation 6, the formula takes the median value of all the pixels within a (2k+1)x(2k+1) window centered at the pixel of interest and assigns that median valueto the pixel in the filtered image.

5 Image Enhancement Techniques

Image enhancement involves adjusting digital images to make them more appropriate for display or additional image analysis. To make it simpler to spot important details, you can, for instance, eliminate noise, sharpen, or brighten a picture

5.1 Histogram

An image histogram is graphical representation between the number of times a partic- ular intensity occurs (i.e. frequency) to the corresponding intensity level (i.e pixel level). Suppose there are Total L possible number of intensity level in the range of [0,g] then the Histogram will be defined as the discrete function as follows:

$$h(i)=\sum_{x} \sum_{y} I(x,y) = i \quad (7)$$

In above equation 7, histogram h(i) depicts the number of times the intensity i occurs. Advantage of histogram is that it helps in providing better variance between the brighter and darker part of the image which helps in improving the image contrast. Histograms are used for image manipulation. It manipulates the image by changing its histogram. Now consider new image J which is formed by manipulating I which can bewritten as

$$J(x , y) = f (I (x , y)) \quad (8)$$

To get a nice image we take such a function f such that it is monotonic in nature that is the function is either strictly increasing or strictly decreasing in the entire range. If we take Non monotonic functions it leads to change in properties of the imagewhich we don't want.

5.2 Histogram equalization

Histogram equalization is a method which helps in modifying the intensity values to improve image contrast.

The main aim of Histogram equalization is to spread out a given histogram so we can fully use the variance between the brighter and darker part of the image. For example, suppose there is an image which is dark, we can assume that most of the intensities lie in the lower range like 10-40,0-30,…….etc. By choosing f to increase the range of the intensity level in order to fully use the available intensities (i.e. Dynamic range), we can improve the image's darker region so that it becomes quite easy to un- derstand the image.

5.3 General method of implementation of Histogram Equalization (HE)

One technique for doing HE is “Cumulative Distribution Function (CDF)”, which stores the pixels having intensities equal to or below a certain number. Let s be a histo- gram and C represents CDF, then h(i) will be indicating the number of pixels with in- tensity i, then

$$C(i) = \frac{\sum_{j \leq i} h(j)}{N},\ h\ (r_k) = n_k \qquad (9)$$

The above equation 9, the CDF (i) is obtained by dividing sum of frequencies of pixels in the image whose intensity level is j, by total number of pixels.

$$h(v) = \frac{round((cdf(v) - cdf\ min)}{(M \times N) - cdfmin)}\ x\ (L-1) \qquad (10)$$

In the above equation 10, h(v) is obtained by multiplying the ratio of rounded value of the difference between minimum value of CDF and CDF(v) to difference of number of pixels and cdfmin and the number of gray scale levels L -1.

Below Table-1 shows an example for CDF and H(v) calculation.

Table 1. Example for CDF and H(v) calculation

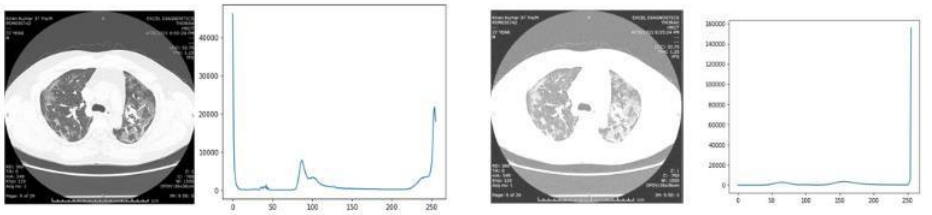
Pixel intensity(v)	CDF(v)	H(v)
52	1	0
55	4	12
58	6	20
59	9	32
60	10	36
61	14	53
62	15	57
63	17	65
64	19	73

5.4 Contrast Limited Adaptive Histogram Equalization (CLAHE)

Various tissues in a CT scan have varied X-ray attenuation values, resulting in different picture intensities. Some locations, however, may look excessively black or too bril- liant, making it difficult to distinguish buildings and diagnose problems. CLAHE tack- les this issue by equalizing the picture's histogram, which involves dispersing the in- tensity values so that the image has a uniform brightness distribution. CLAHE is a dig- ital image processing technology used to improve the appearance of medical pictures, notably Computed Tomography (CT) scans. The primary goal of CLAHE is to boost contrast in low-contrast areas of a picture, making features more visible and identifia- ble.

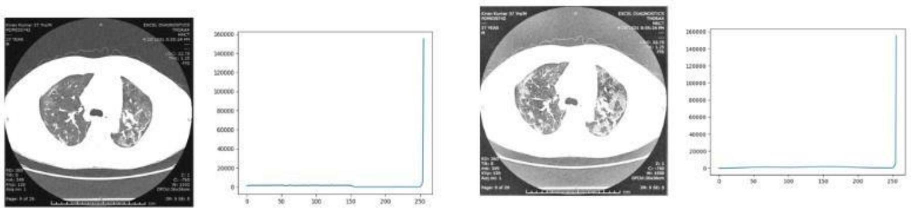
It works by breaking the image into smaller tiles, computing histograms of the intensity values in each tile, then stretching the histograms to boost contrast. The con- trast stretching is limited to avoid over-enhancement in high-contrast regions, which can result in over-saturation and detail loss.

Here, Fig. 7 represents CT scan image of Covid patient, its Histogram, Gauss- ian noised image and its histogram and Fig. 8 represents CT scan image of Covid pa- tient, Histogram, CLAHE enhanced image and its histogram. The observation from this is that CLAHE enhanced image has retained/shows the important features required foranalysing the disease.



Original image Histogram of original image Gaussian noised image image Histogram of Gaussian image

Fig. 7. CT scan image of Covid patient, its Histogram, Gaussian noised image and its histogram



HE image Histogram of CLAHE CLAHE enhanced image Histogram of CLAHE enhanced image

Fig. 8. CT scan image of Covid patient, Histogram, CLAHE enhanced image and its histogram

6 Materials And Methods

Here a set of x-ray and CT scan images were taken and all kinds of noises (Gaussian, Salt & pepper, Uniform) were introduced. On these noised images mean and median filters of 3x3 and 5x5 are applied to generate resultant images. Then various parameters such as MSE, PSNR, SSIM and NC are calculated, tabulated, and analyzed.

In the next step, on each of these filtered images, image enhancement tech- niques such as Histogram Equalization and CLAHE are applied and new set of images were generated. Then various parameters such as MSE, PSNR, SSIM and NC are cal- culated, tabulated, and analyzed.

7 Results And Discussion

Proposed system is evaluated on x-ray and CT scan images from Kaggle database and images from Prima Diagnostics private center in Bangalore. Experiment is carried outusing Python and Open CV.

Totally on 156 images various noises, filters and enhancements are applied. Out of which it is found that in Gaussian, salt & pepper, 3x3 mean filter found to be better than others. In case of uniform noised images noised images 5x5 mean filter found to be better as shown in tables 2 to 4.

With respect to image enhancement techniques on these filtered images of vari- ous noises and filters, among HE with Gaussian noise 3x3 median filtered HE found to be effective and among CLAHE techniques, CLAHE on noised image is found to be effective.

Table 5 represents MSE, RMSE, PSNR, NC performance parameter values for Gaussian noised images, HE and mean and median HE (Image Enhancement), and Table 6 represents MSE, RMSE, PSNR, NC performance parameter values for Gauss- ian noised images, CLAHE and mean and median CLAHE (Image Enhancement), which shows that 3x3 median HE outperformed over other techniques and CLAHE outperformed.

If we compare, HE and CLAHE technique on Gaussian noised image, CLAHE found to be better with respect SSIM. In case of CLAHE, with respect to SSIM param- eter on Gaussian noised image, 5x5 mean CLAHE was giving better results than others. Fig 9, 10 shows the graphs of Gaussian noised image mean and median filtered parameters and Gaussian noised image mean, median filtered and enhanced parameters which represents the average values over 156 images.

Table 2. MSE, RMSE, PSNR, NC performance parameter values for mean and median filters on Gaussian noised images

	Noised	3x3mean	5x5mean	3x3median	5x5median
MSE	84.5938	74.6966	75.7144	75.6652	74.8902
PSNR	28.8574	29.3978	29.2563	29.3418	29.3866
SSIM	0.5697	0.6082	0.5405	0.6036	0.5532
NC	0.9719	0.9704	0.9673	0.9712	0.9691

Table 3. MSE, RMSE, PSNR, NC performance parameter values for mean and median filters on Salt and pepper noised images

	Noised	3x3mean	5x5mean	3x3median	5x5median
MSE	31.3984	103.8818	106.2134	28.1318	31.4795
PSNR	33.1617	27.9654	27.8690	33.6388	33.1505
SSIM	0.0669	0.1780	0.2373	0.5106	0.7273
NC	0.8297	0.9573	0.9677	0.9779	0.9921

Table 4. MSE, RMSE, PSNR, NC performance parameter values for mean and median filters on Uniform noised images

	Noised	3x3mean	5x5mean	3x3median	5x5median
MSE	82.8475	86.3540	82.9837	89.5595	87.9356
PSNR	28.9480	28.7680	28.9409	28.6097	28.6892
SSIM	0.4285	0.5129	0.4951	0.4554	0.4532
NC	0.9631	0.9698	0.9672	0.9685	0.9672

Table 5. MSE, RMSE, PSNR, NC performance parameter values for Gaussian noised images, HE and mean and median HE (Image Enhancement)

	Noised	HE	3x3 mean HE	5x5 mean HE	3x3 median HE	5x5 median HE
MSE	82.8475	81.6867	78.9607	84.5624	78.2041	78.2692
PSNR	28.9480	29.0093	29.1567	28.8590	29.2265	29.1949
SSIM	0.4285	0.3286	0.4793	0.4530	0.4793	0.4500
NC	0.9631	0.9843	0.9913	0.9671	0.9913	0.9892

Table 6. MSE, RMSE, PSNR, NC performance parameter values for Gaussian noised images, CLAHE and mean and median CLAHE (Image Enhancement)

	Noised	CLAHE	3x3 mean CLAHE	5x5 mean CLAHE	3x3 median CLAHE	5x5 median CLAHE
MSE	82.8475	81.1699	83.1962	82.9837	85.0056	87.1024
PSNR	28.9480	29.0369	28.9298	28.9409	28.8363	28.7305
SSIM	0.4285	0.4018	0.4754	0.4951	0.4165	0.4083
NC	0.9631	0.9440	0.9659	0.9672	0.9577	0.9619

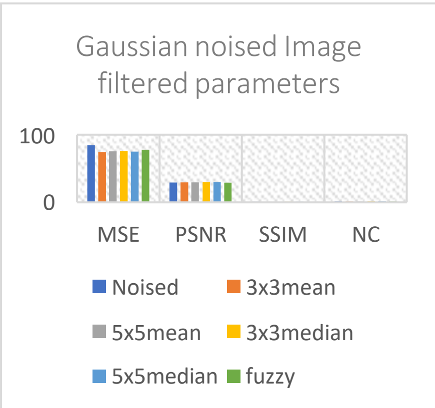


Fig. 9. With Gaussian noised image, mean and median filtered parameters

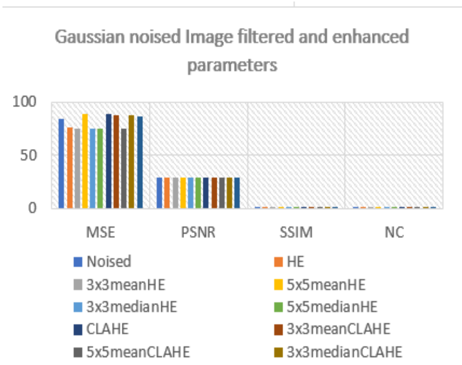


Fig. 10. With Gaussian noised image, mean, median filtered and enhanced image parameters

8 Conclusion And Future Work

In this paper, few filtering techniques (like median 3x3 filters, mean 3x3 filters, median 5x5 filters, mean 5x5 filters, salt-and-pepper filters) and image enhancement techniques (like Histogram Equalization, CLAHE) are explored and implemented. The implementation is done using Python and OpenCV libraries for image enhancement of CT scan. Initially we applied filters on the x-ray/CT-scan images to remove noise and sharpen the image, making it easier to identify key features of the image. It is observed that the 3x3 median filter works better than other filtering techniques for Gaussian and Salt and peppered images. And 5x5 mean filter works better than other filtering techniques for Uniform images.

While contrast enhancement will improve the brightness differences between the objects and the background. From the result, we found that out of Histogram Equaliza- tion and CLAHE, CLAHE delivers a more enhanced and efficient image.

CNN techniques for denoising and image enhancement are composed to future work.

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