Assignment 1

Submitted by EE19S042

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1 Task 1 : Geometric transforms

1.1 Image Translation

For part 1 of task image is being translated by 4.5 in x-direction and 3.4 in y-direction as given and resultant image is displayed as in figure [1].The translated image pixel values is filled using bilinear interpolation for target to source mapping to avoid holes in the image and ensuring all pixels of translated image being filled.It is also been compared with the inbuilt translate function of MATLAB.

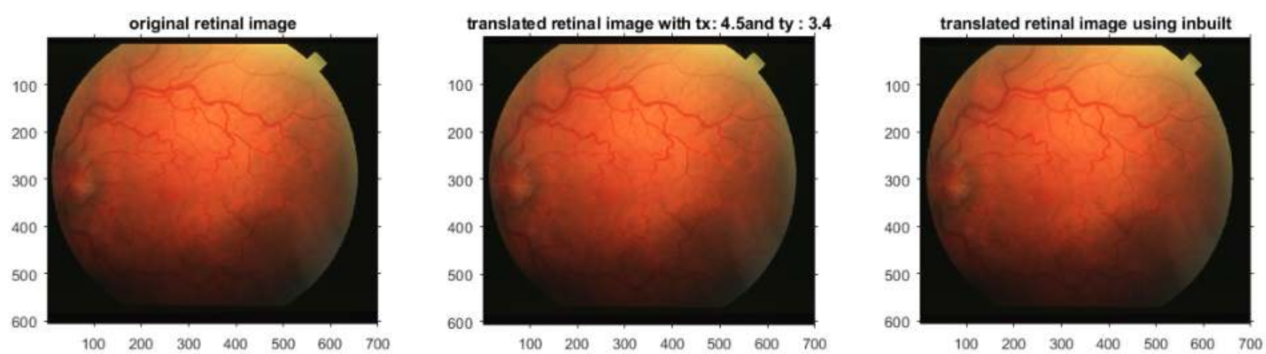


Figure 1: Translated image of t_x =4.5 and t_x =3.4

For comparison another translated image of translation 45 pixels in x-direction and 34 pixels in y-direction is as shown in figure [2].Elapsed time of it is 1.831631 seconds.

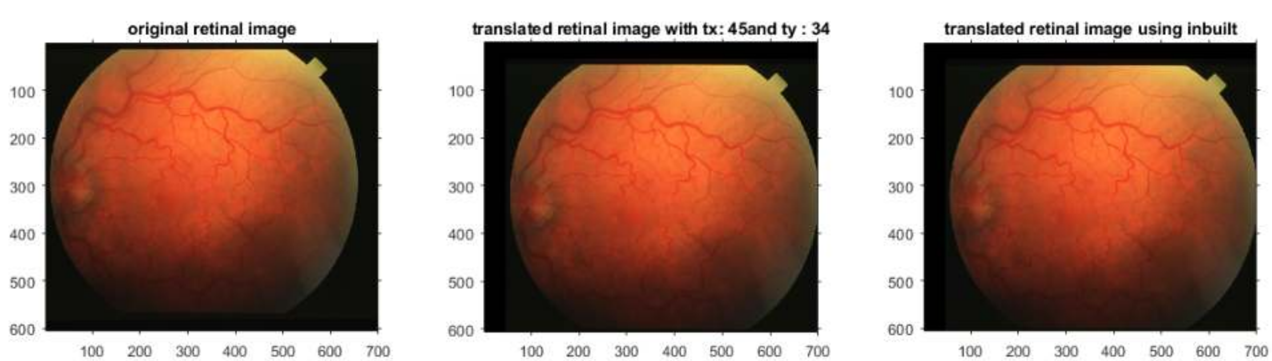


Figure 2: Translated image of t_x =45 and t_x =34

1.2 Image Rotation

For part 2 of task 1 image is being rotated by 35° and −125° as given and resultant image is displayed as below.The image is rotated with respect to its center pixel of the image.Image is being rotated using rotation matrix :

$$\begin{bmatrix} cos(\theta) & sin(\theta) \\ -sin(\theta) & cos(\theta) \end{bmatrix}$$

The rotated image pixel values is filled using bilinear interpolation for target to source mapping to avoid holes in the image and ensuring all pixels of rotated image being filled as before.It is also been compared with the MATLAB inbuilt rotate function.Elapsed time is 3.440965 seconds and 5.517271 seconds respectively for rotation of 35° and −125° as shown in[3] and [4].

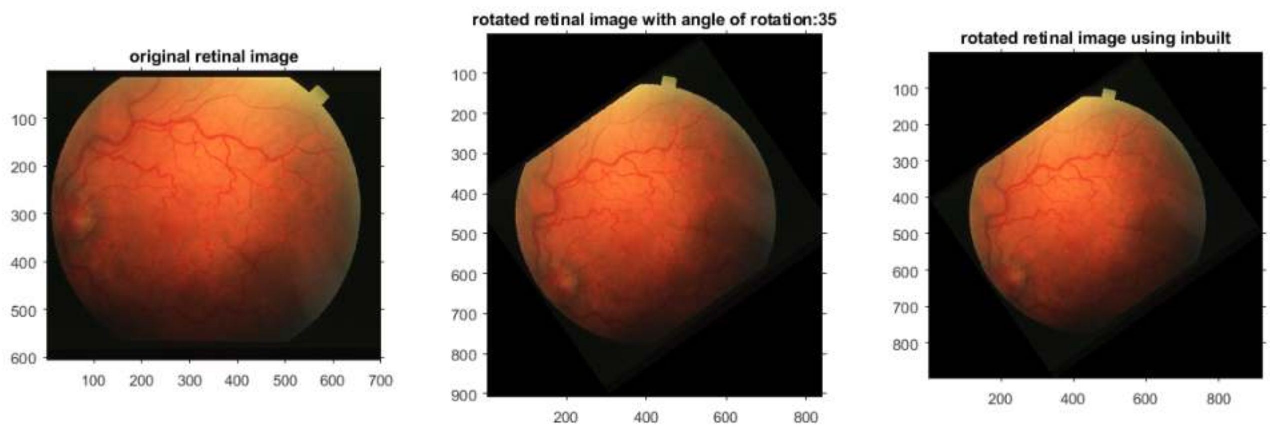


Figure 3: Rotated image of $\theta = 35$ °

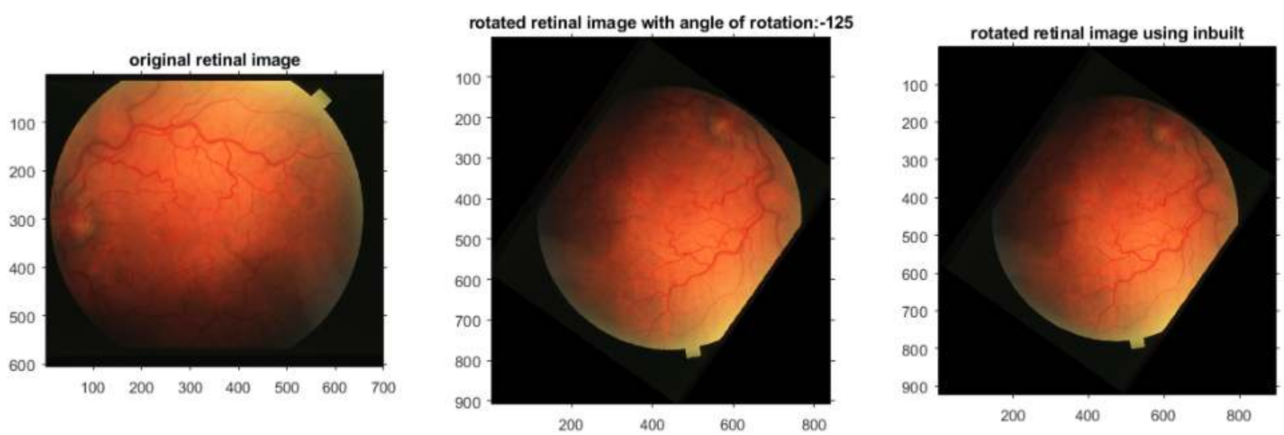
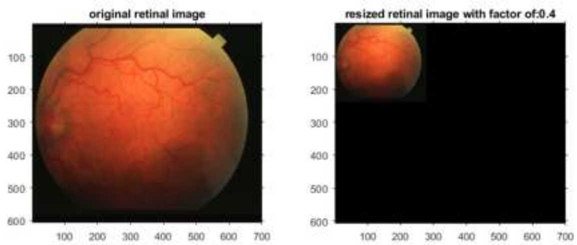


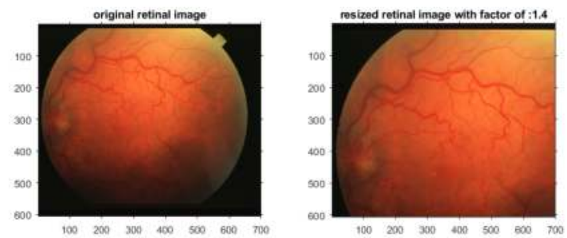
Figure 4: Rotated image of $\theta =$ -125 °

1.3 Image Scaling

For part 3 of task 1 image is being scaled by 0.4 and 1.4 as given and resultant image is displayed as in figure [5].The scaled image pixel values is filled using bilinear interpolation for target to source mapping to avoid holes in the image and ensuring all pixels of scaled image being filled as before.



(a) Image resized with a factor of 0.4



(b) Image resized with a factor of 1.4

Figure 5: Resized Image

For comparing it with the MATLAB inbuilt translate function the window size of the scaled image is varied with the scale function and the results are shown in figure[6] and [7].Elapsed time is 0.349579 seconds and 2.525669 seconds respectively for rotation of 0.4 and 1.4.

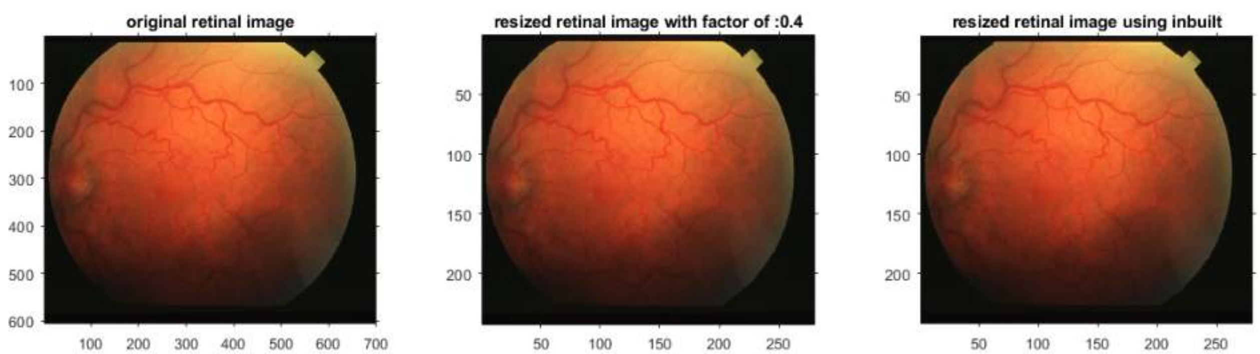


Figure 6: Image resized with a factor of 0.4 along with its inbuit

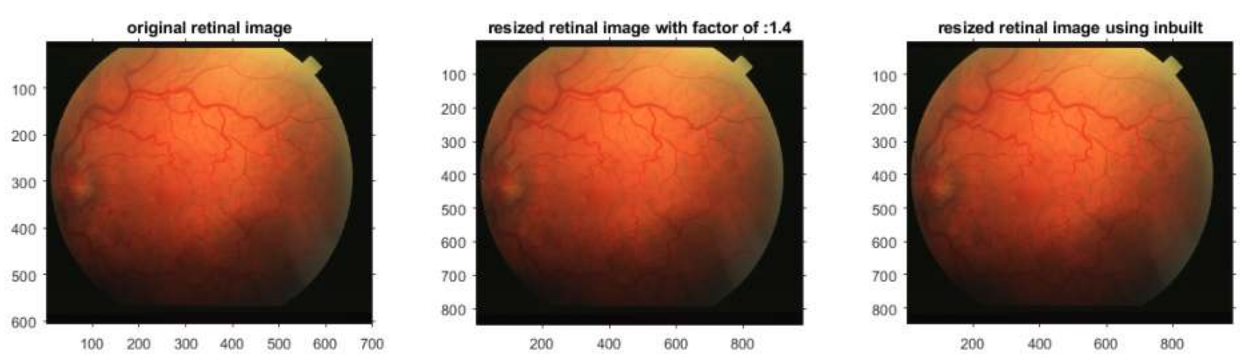


Figure 7: Image resized with a factor of 1.4 along with its in buit

2 Task 2 : Histograms

Histogram is a graphical representation of the intensity distribution of an image. In simple terms, it represents the number of pixels for each intensity value considered. Histogram Equalization technique is used to improve contrast in images. It accomplishes this by effectively spreading out the most frequent intensity values, i.e. stretching out the intensity range of the image.The process of histogram equalisation is to convert the gray value corresponding to each pixel in the original image into the equalised gray value using a conversion function. Mathematically, Let $M \times N$ be the total number of pixels of the input image, L is the total number of gray levels of the input image, n_j total number of pixels of gray value j, the conversion function of histogram equalisation is:

$$s_k = T(r_k) = round(cdf(r_j) \times (L - 1)) \tag{1}$$

where $cdf(r_j) = \sum \frac{n_j}{MN}$

Algorithm:

1. If we consider any gray scale image (x),n_i be the number of occurrence of gray level i and a probability function of occurrence of a pixel of level i in image (x) is,

$$p_x(i) = p(x = i) = \frac{n_i}{n}, 0 <= i < L \tag{2}$$

2. For each pixel in the input image calculate the cdf for this image which is sum of probabilities till that point.
3. Equalize the cdf using the formula,$s_k = T(r_k) = round(cdf(r_j) \times (L - 1))$
4. For each pixel in the output image calculate the histogram equalization result.

Here, for histogram equalisation the color components of given iris image is separated in to different parts and the equalised histogram is computed for these. For equalisation ,I have followed 3 methods. First is equalizing individual R,G,B components and then concatenate it to get the equalised color image. Second is averaging the equalised R,G,B images to get the equalised image.Third is converting RGB image in to HSI(Hue,Saturation,Intensity) color space and the equalise only the intensity component and finally convert the HSI image into RGB one to get the equalised enhanced image. The result of these methods is being compared with inbuilt histogram equalisation method.The results and equalised histogram are as in [8].

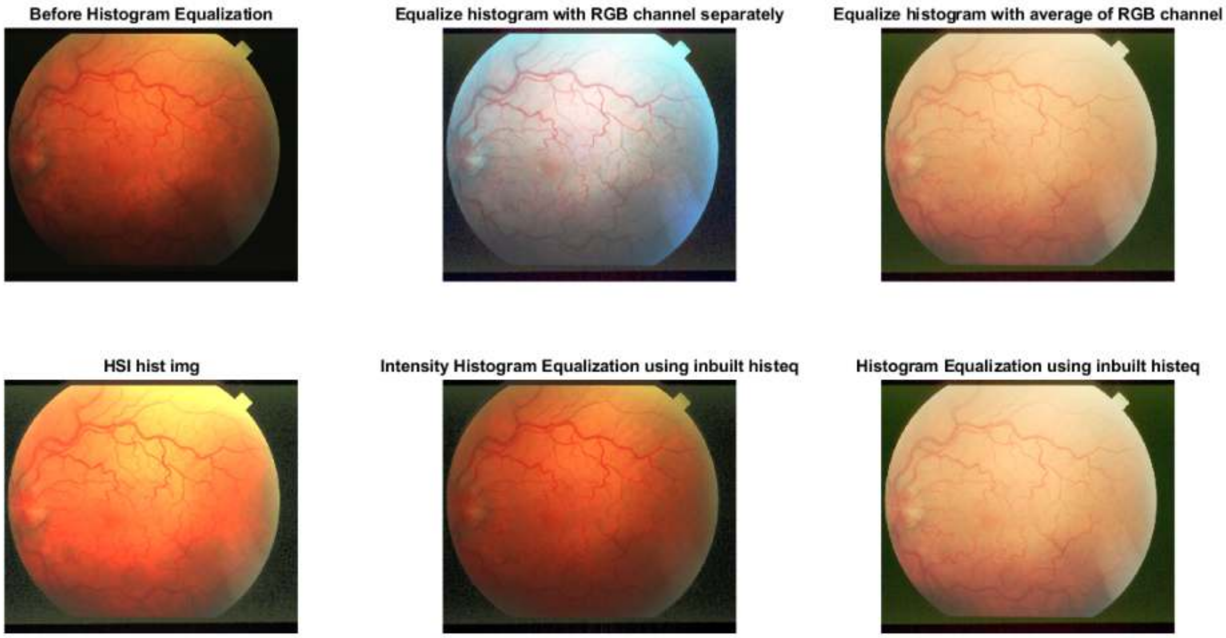


Figure 8: Images of Histogram equalisation and merging using different techniques

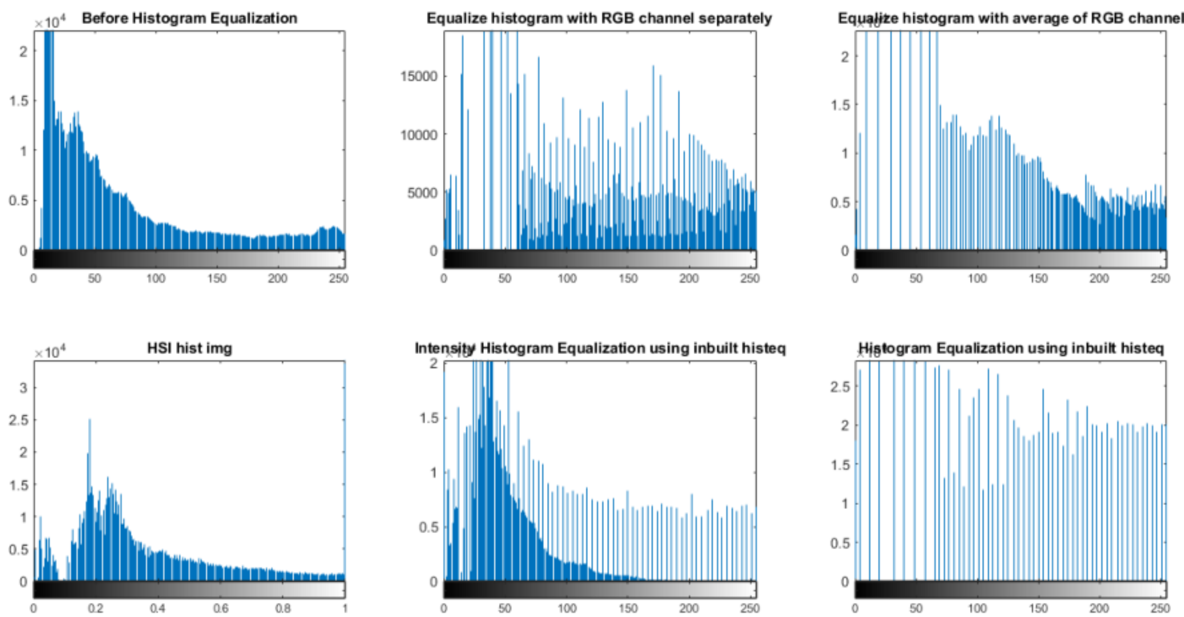


Figure 9: Histogram plots of Histogram equalisation and merging using different techniques

Observation: As we can see from the plot equalising RGB individually and storing them individually for corresponding channel gives appealing result, while merging it result in insignificant color to become dominant(in this case blue).Histogram equalisation using intensity component of HSI increase the brightness value more.The histograms of the corresponding images is as shown in figure [9]

3 Task 3 : Understanding of various types of noise and filters

3.1 Noise Generation in image

In this section generation of various noise found in medical imaging ,Its filtering and enhancement steps are discussed.

3.1.1 Introducing salt paper noise

It is also known as impulse noise.It is occurred during acquisition process, storage transaction and processing of images.In impulse noise lost the information details and degrades the quality of image.The distribution of impulse noise is given as,

$$f(N) = \begin{cases} 0 & if t < P_a \\ 255 & if t >= P_a \ \& \ t < P_a + P_b \end{cases} \tag{3}$$

Where, P_a is the probability of pepper noise and P_b is the probability of salt noise. t is random numbers whose size is as of size of image.

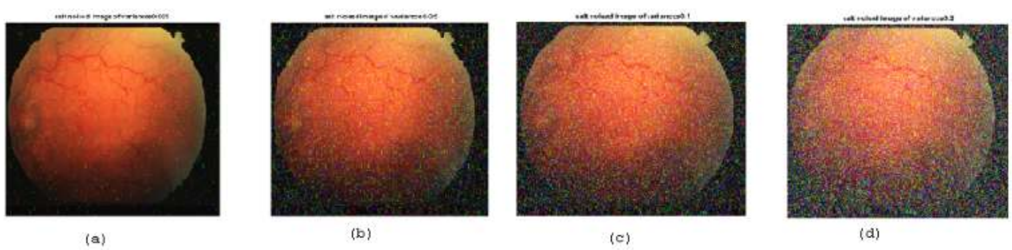


Figure 10: Salt noised image with probability of pepper 0 and salt as (a) 0.005 (b)0.05 (c)0.1 (d)0.2 respectively

For adding pepper noise vary probability of pepper noise in between 0 to 1.

3.1.2 Introducing Gaussian noise

It is also known as Amplifier noise and generated as a result of thermal vibration of atoms and radiation of warm objects.This noise like Gaussian distribution in structure.It is generated using Gaussian function given as,

$$W(n) = \frac{1}{\sqrt{2 * \pi * \sigma^2}} * \exp\left(\frac{(N-m)^2}{\sigma^2}\right) \tag{4}$$

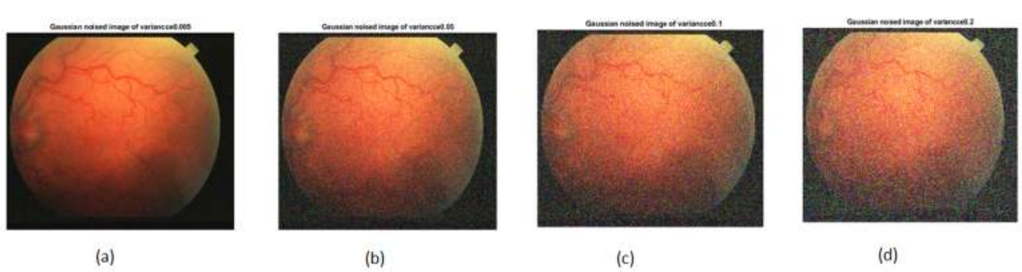


Figure 11: Gaussian noised image with mean 0 and variance as (a) 0.005 (b)0.05 (c)0.1 (d)0.2 respectively

3.2 Noise filtering and Image enhancement

This step describes about different filtering technique implementation for removing noise generated in previous step.The overall algorithm for noise filtering and image enhancement can be described as follows,

STEP 1: Reading noisy image $N(x, y) = I(x, y) + \eta(x, y)$ where N(x,y) is the noisy image, I(x,y) is the original image and $\eta(x, y)$ is the additional noisy pixels.
STEP 2: Decomposition of the noisy image into its red, green and blue channel.
STEP 3: Applying filtering technique to remove noise from the individual channel, results de-noised red channel, de-noised green channel and de-noised blue channel.
STEP 4: Contrast enhancement and smoothening of de-noised image by CLAHE(Contrast Limited Adaptive Histogram Equalisation, results de-noised and enhanced red channel, de-noised and enhanced green channel and de-noised and enhanced blue channel.
STEP 5: Merge all the three denoised and enhanced components together to form denoised and enhanced RGB fundus image.
STEP 6: Repeat step 1 to 5 for different types of filters, noise and noise variances.

The Block diagram of the algorithm is as shown in figure [12] [1]

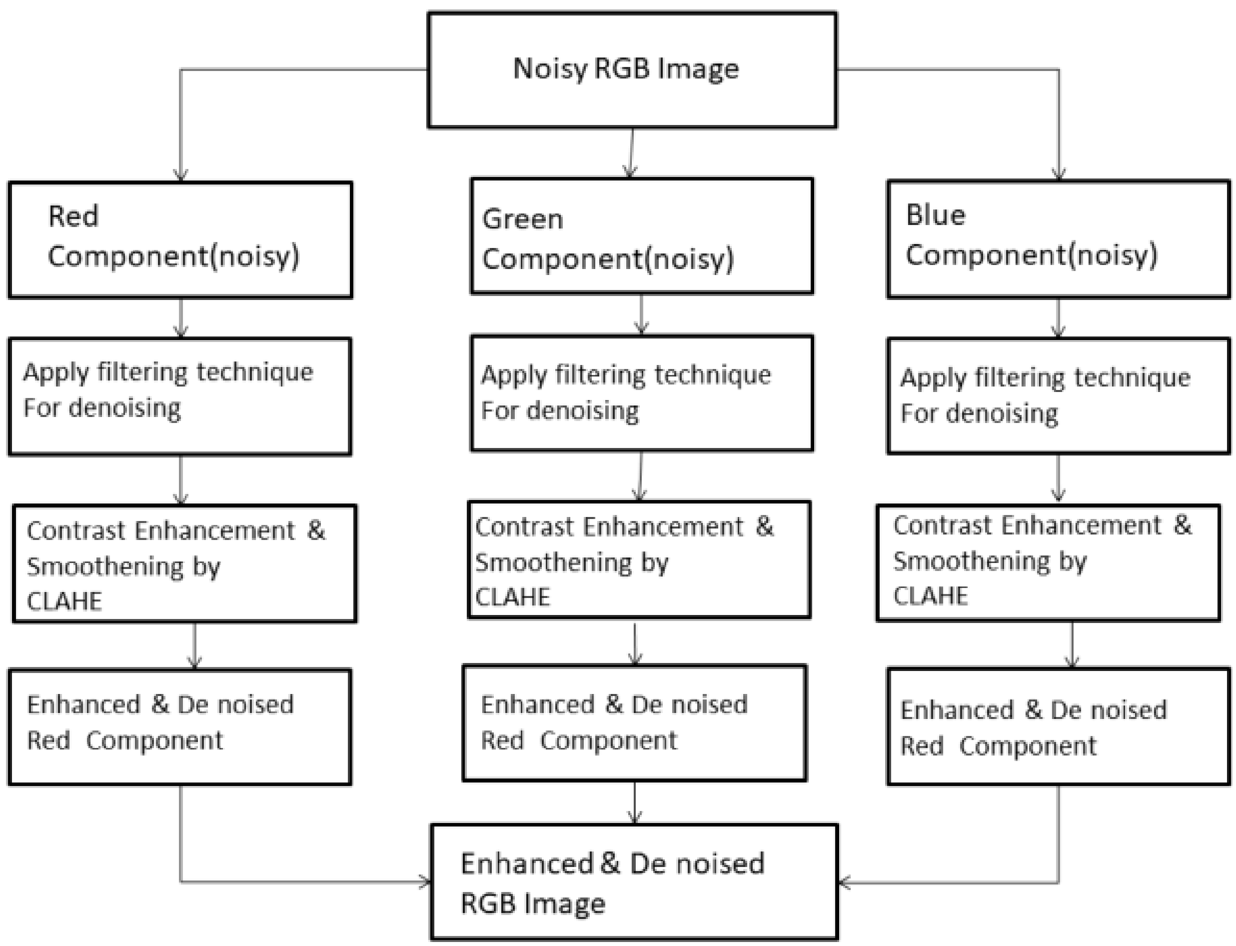


Figure 12: Block Diagram of Image de noising and enhancement using CLAHE

[1]for image denoising and enhancement using CLAHE algorithm https://www.sciencedirect.com/science/article/abs/pii/S0030399218306637.

$\boldsymbol{ContrastLimitedAdaptiveHistogramEqualisationtechnique(CLAHE)}$ **:** Contrast limited adaptive equalization is a modified part of adaptive histogram equalization. In this method enhancement function is applied over all neighborhood pixels and transformation function is derived.CLAHE limits the contrast amplification to reduce amplified noise. It does so by distributing that part of the histogram that exceeds the clip limit equally across all histograms.The algorithm for CLAHE is give as,
Step 1: Acquisition process of a color image.
Step 2: Get all input values which is used in enhancement process like number of regions in row and Column direction separately, dynamic range (number of bins used in histogram transform function), cliplimit, distribution parameter type.
Step 3: Original image divide into some region using inputs given.
Step 4: Process applied over tile (contextual region).
Step 5: Generate gray level mapping and clipped histogram. In contextual region numbers of pixels are equally divided in each gray level so, average number of pixels is gray level is described as follow:

$$N_{avg} = \frac{N_{CR-XP} * N_{CR-XP}}{N_{gray}} \tag{5}$$

Where N_{avg} = average number of pixels
N_{CR-XP} = number of pixels in X-direction of contextual region
N_{CR-XP} = number of pixels in Y-direction of contextual region
N_{gray} = number of gray levels of contextual region.

After that calculate the actual cliplimit

$$N_{CL} = N_{CLIP} * N_{avg} \tag{6}$$

Step 6: Interpolate gray level mapping in order to create enhanced image. This process use four pixel cluster and apply mapping process .Then each of mapping tiles will partly overlap in the image region. After that a single pixel will be extracted and four mapping is applied to that pixel. Interpolate between that results and get enhance pixel, repeat over an image.
[2]

3.2.1 Noise filtering using Mean filter :

It is a spatial (linear) filtering technique that replaces the value of pixels in the window with the mean of the pixels value in that window. It is usually used for the purpose of de-noising and smoothening of the image. The noise that mean filter efficiently removes from fundus image is grainy noise. Poor in preservation of useful details in image after noise removal.The result of Mean filter for filtering out salt noise of variance 0.005 and 0.05 is as shown in figure [13] and [14]respectively. Also the result of Mean filter for filtering out Gaussian noise of variance 0.005 and 0.05 is as shown in figure [15] and [16]respectively.

[2] url for CLAHE algorithm `https://ieeexplore.ieee.org/document/6968381`.

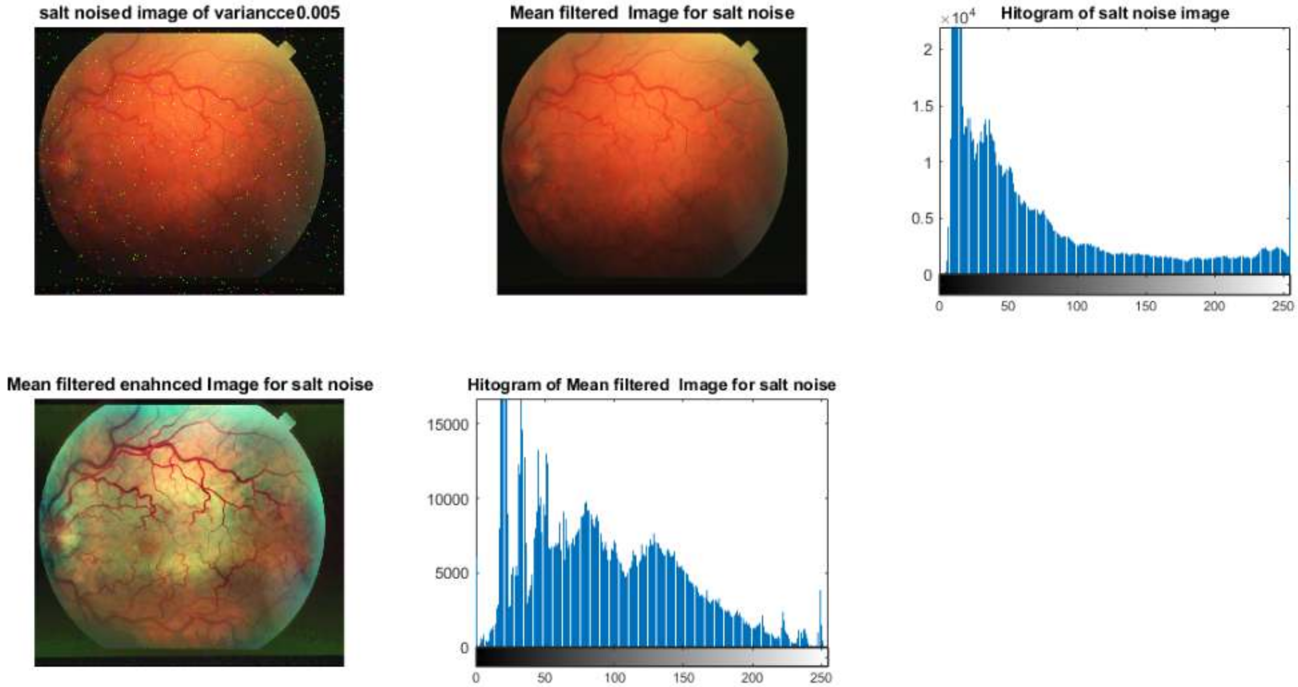


Figure 13: Mean filter for salt noise of variance 0.005 along with its enhanced image using CLAHE technique and its histograms.

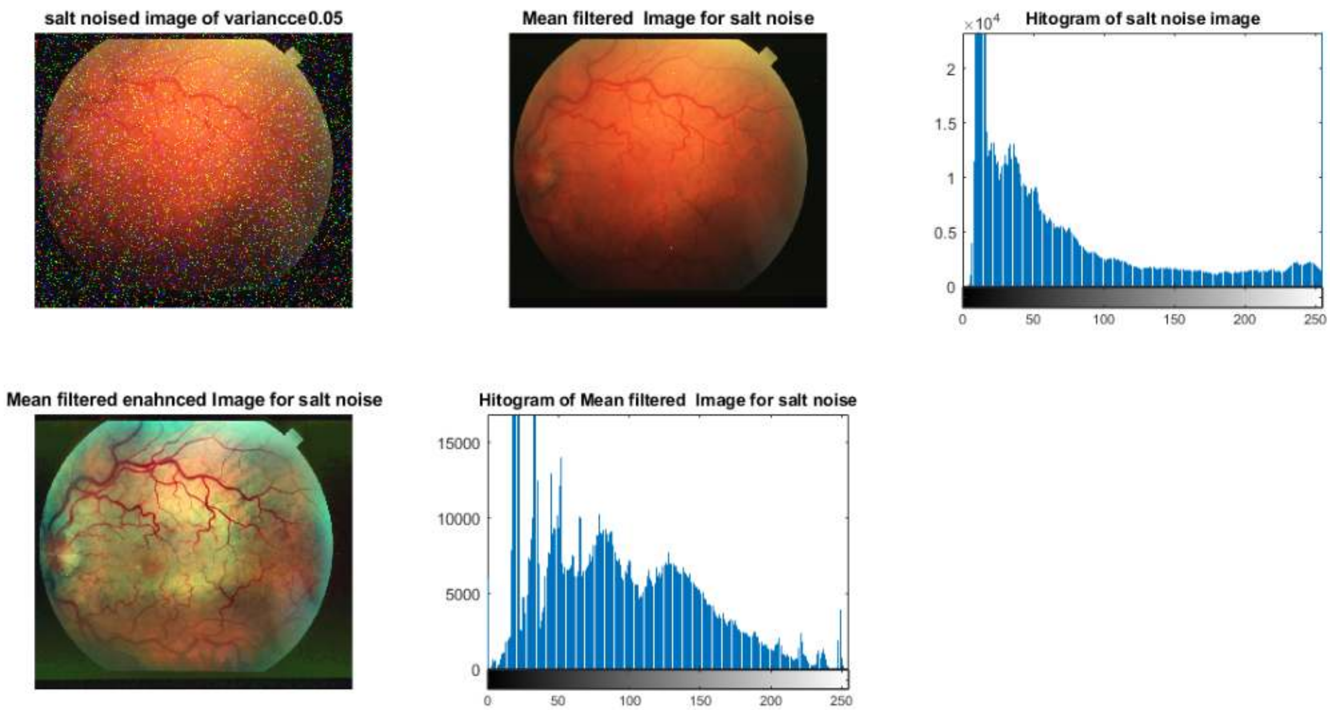


Figure 14: Mean filter for salt noise of variance 0.05 along with its enhanced image using CLAHE technique and its histograms.

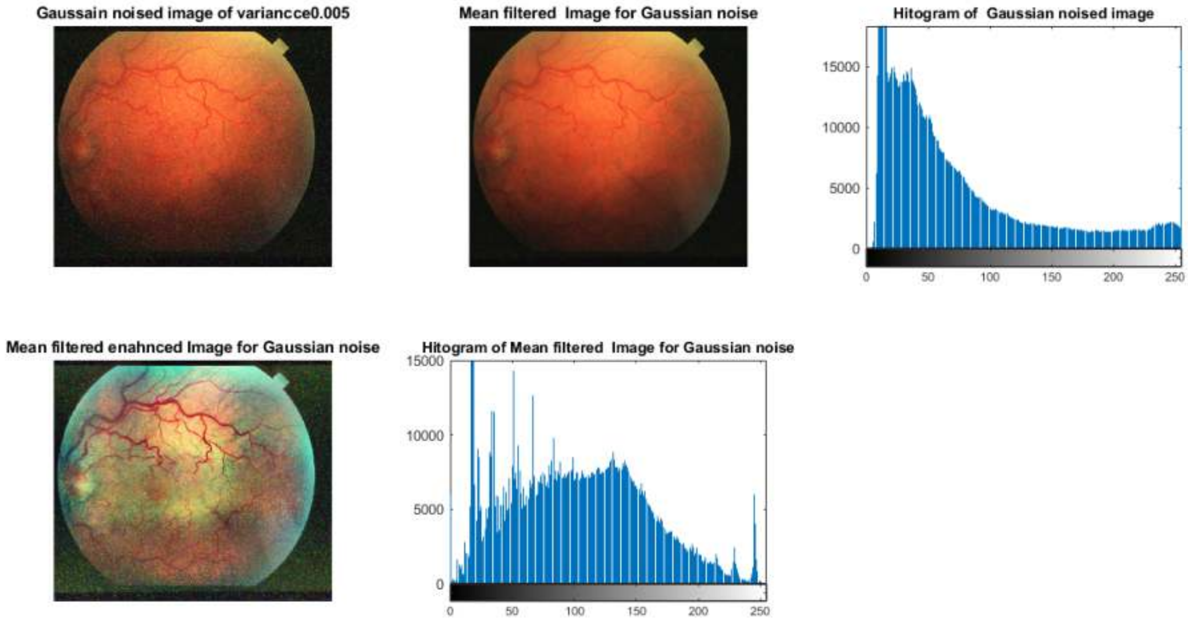


Figure 15: Mean filter for Gaussian noise of variance 0.005 along with its enhanced image using CLAHE technique and its histograms.

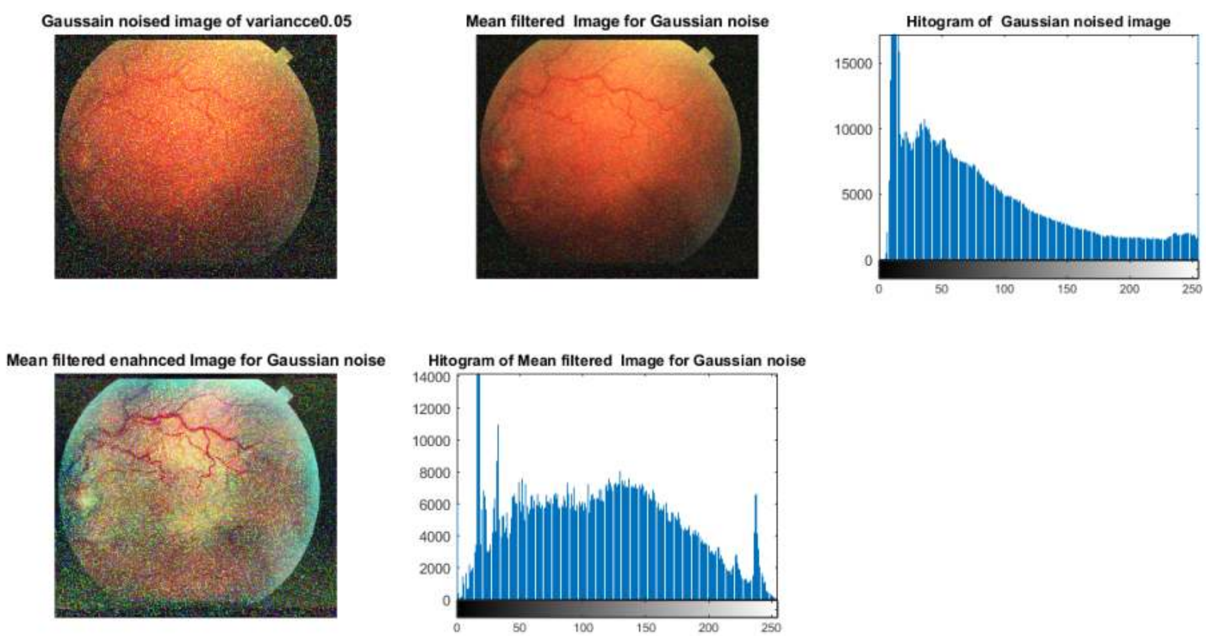


Figure 16: Mean filter for Gaussian noise of variance 0.05 along with its enhanced image using CLAHE technique and its histograms.

3.2.2 Noise filtering using Median filter :

It is a spatial but non-linear filtering technique to remove noise from the image as well as preserve the edge degradation that happens in average filtering. In median filtering, the pixel value that is corrupted is replaced by the median of that window pixel values. Median filter works well for the fundus image enhancement as compared to other linear filters. The result of Median filter for filtering out salt noise of variance 0.005 and 0.05 is as shown in figure [17] and [18]respectively. Also the result of Median filter for filtering out Gaussian noise of variance 0.005 and 0.05 is as shown in figure [19] and [20] respectively.

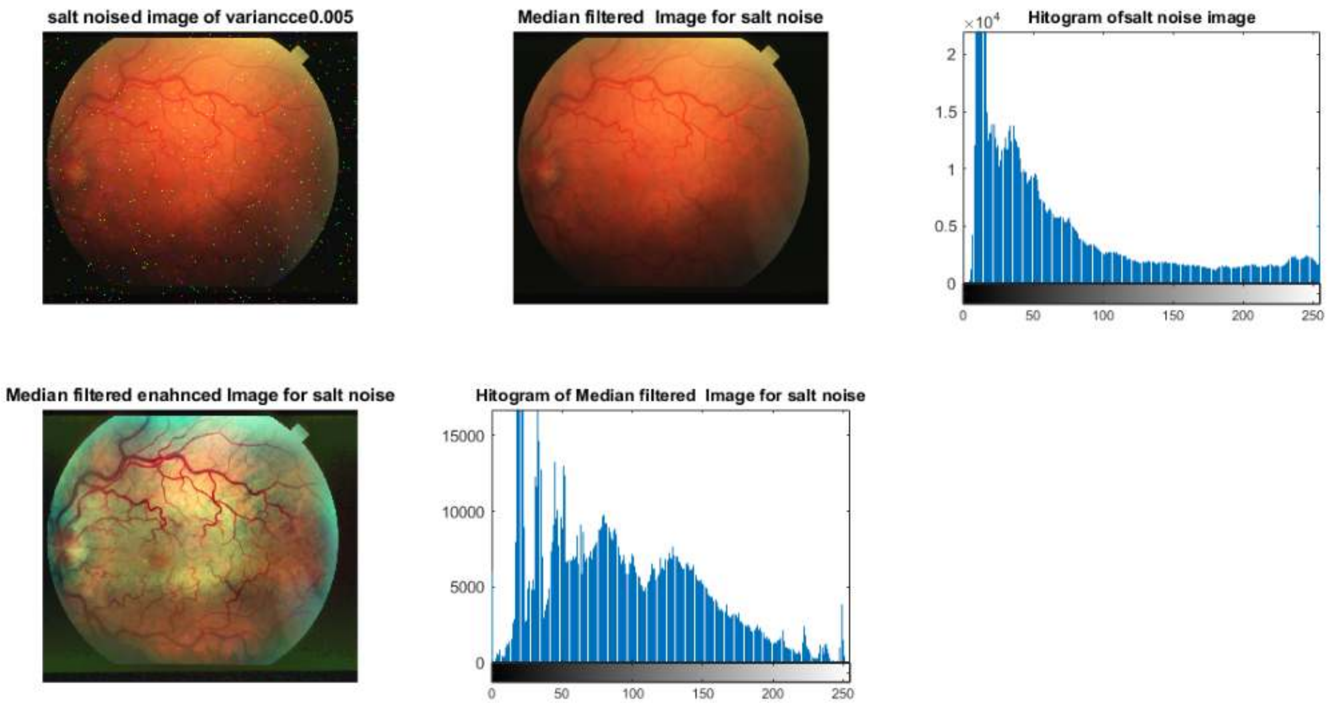


Figure 17: Median filter for salt noise of variance 0.005 along with its enhanced image using CLAHE technique and its histograms.

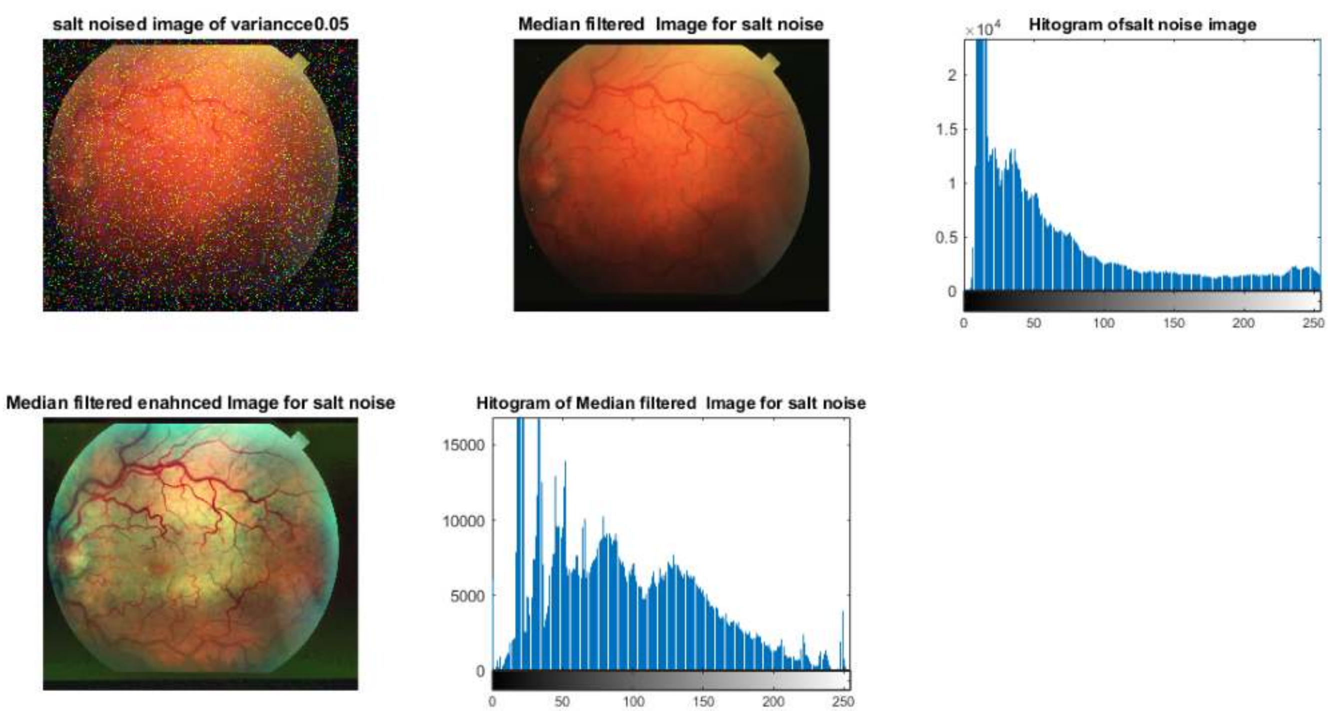


Figure 18: Median filter for salt noise of variance 0.05 along with its enhanced image using CLAHE technique and its histograms.

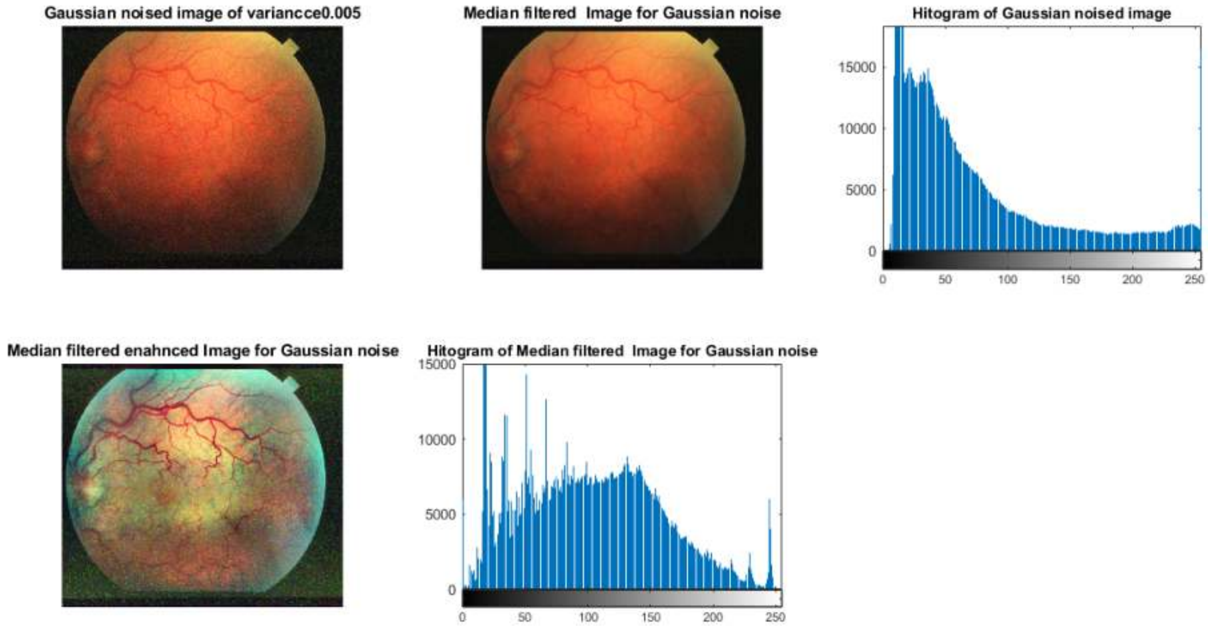


Figure 19: Median filter for Gaussian noise of variance 0.005 along with its enhanced image using CLAHE technique and its histograms.

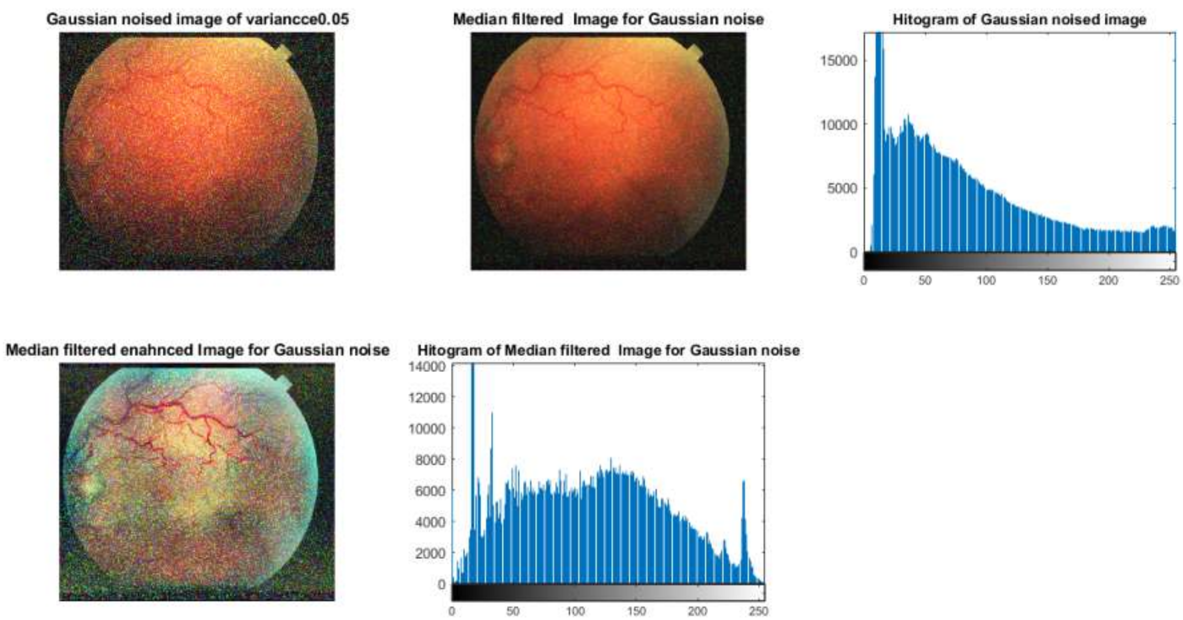


Figure 20: Median filter for Gaussian noise of variance 0.05 along with its enhanced image using CLAHE technique and its histograms.

3.2.3 Noise filtering using Gaussian filter :

It is a linear filter that is used to remove noise from the image along with the blurring of image similar to average filter. It differs from average filter in the aspect that it uses different kernel from mean filter which is in the shape of bell curve (Gaussian PDF). In 2-Dimensional, Gaussian has the equation:

$$G(x, y) = \frac{1}{2 * \pi * \sigma^2} \exp -(\frac{x^2 + y^2}{2\sigma^2}) \tag{7}$$

where mean is (0,0) and σ^2 is the variance between 0 to 1. The result of Gaussian filter for filtering out salt noise of variance 0.005 and 0.05 is as shown in figure [21] and [22]respectively. Also the result of Gaussian filter for filtering out Gaussian noise of variance 0.005 and 0.05 is as shown in figure [23] and [24] respectively.

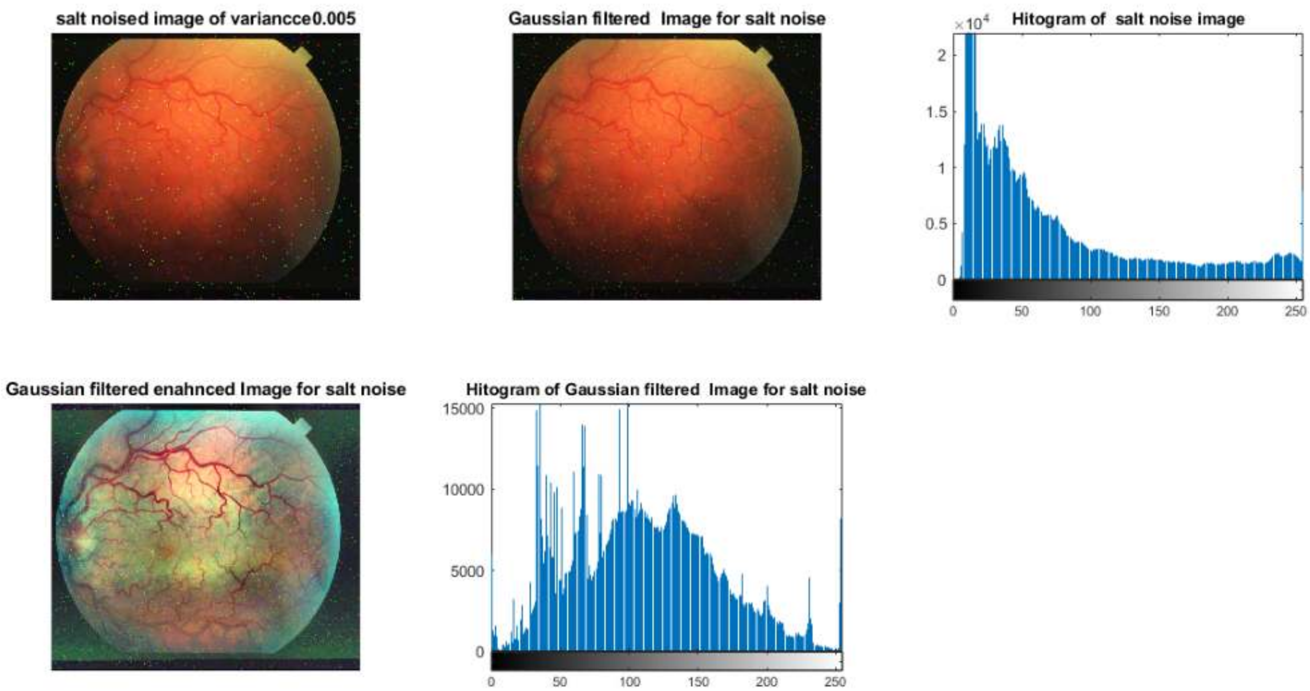


Figure 21: Gaussian filter for salt noise of variance 0.005 along with its enhanced image using CLAHE technique and its histograms.

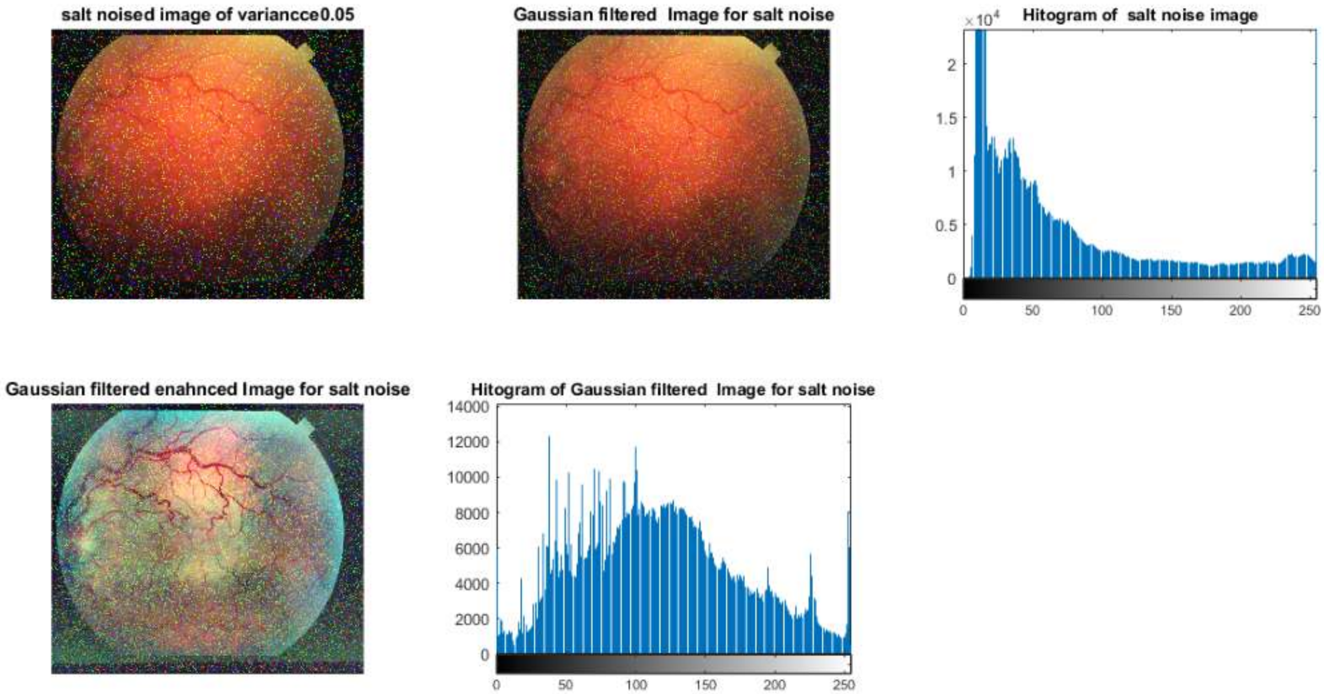


Figure 22: Gaussian filter for salt noise of variance 0.05 along with its enhanced image using CLAHE technique and its histograms.

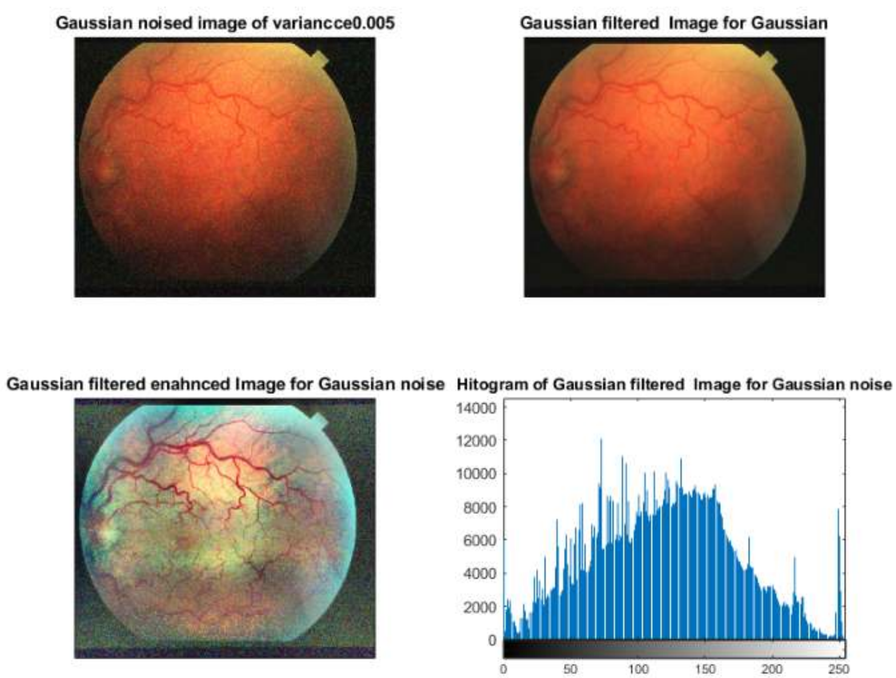


Figure 23: Gaussian filter for Gaussian noise of variance 0.005 along with its enhanced image using CLAHE technique and its histograms.

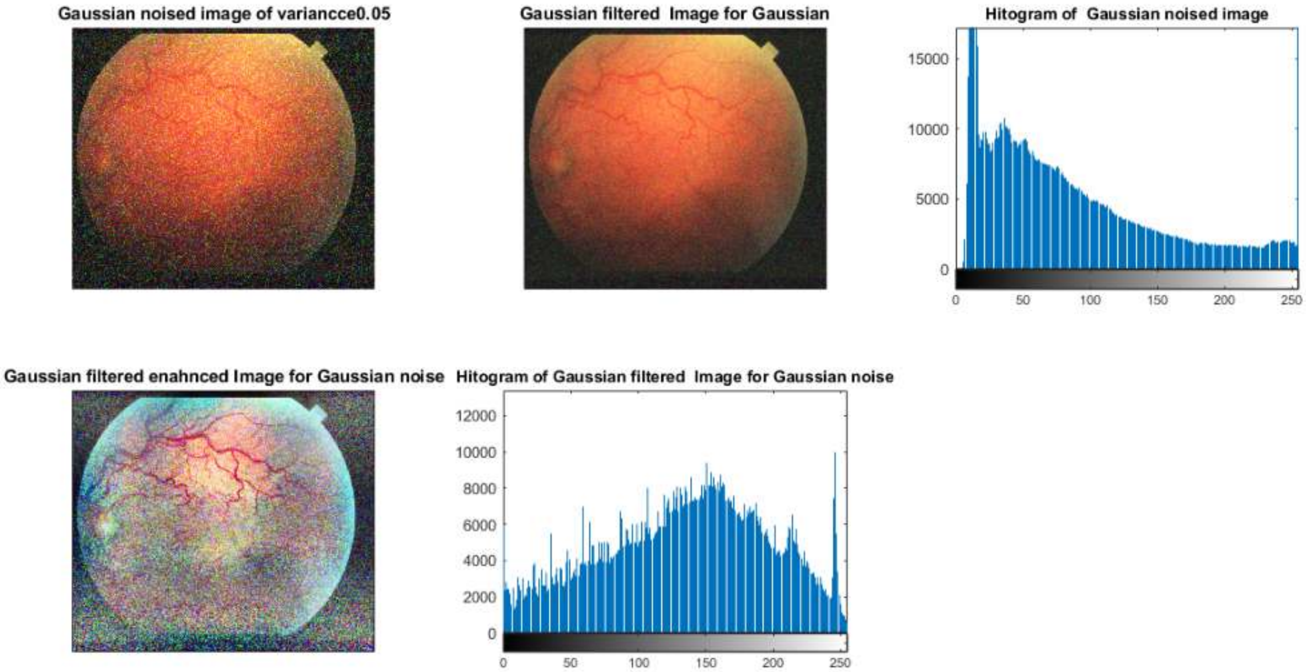


Figure 24: Gaussian filter for Gaussian noise of variance 0.05 along with its enhanced image using CLAHE technique and its histograms.

3.3 Peak Signal to Noise Ratio (PSNR) Caluculation

As the name explains, it is the ratio of the maximum/peak value of the signal to the noisy signal value. PSNR formally describes the quality of the reconstructed image after the application of any technique on it. Higher the PSNR, better the quality of reconstructed image. PSNR is expressed as:

$$PSNR = 10 \log_{10} \frac{(peakvalue)^2}{MSE} \tag{8}$$

where Peakvalue is the maximum difference in the input image value and MSE is Mean Square Error and is computed as

$$MSE = \frac{1}{m \times n} \sum_{i=1}^{m \times n} (\hat{y}(i,j) - y(i,j))^2 \tag{9}$$

where $m \times n$ specifies the size of the image, $\hat{y}(i,j)$ is the recovered image and y(i,j) is the Original image. Table below shows the PSNR values for different filtering techniques and filtering along with CLAHE against different attacks or noises at different noise variances level σ_n^2 in db.

Filters	Noise Variance	Noise Type	
		Salt & Pepper Noise	Gaussian Noise
Median	0.005 0.02 0.05 0.1 0.2	30.0454 23.9987 20.0398 17.0705 14.1451	32.2050 26.2462 22.3937 19.6134 17.2016
Median + CLAHE	0.005 0.02 0.05 0.1 0.2	19.6678 18.8480 17.5991 16.1297 14.2140	18.7206 27.1776 17.2121 16.5047 15.6188
Mean	0.005 0.02 0.05 0.1 0.2	30.5124 24.5726 20.7563 18.0139 15.5267	32.9780 26.2544 23.3811 20.6350 18.2710
Mean + CLAHE	0.005 0.02 0.05 0.1 0.2	19.4188 18.0669 16.3561 15.0488 13.9583	18.3251 17.8462 15.9703 15.2666 14.8935
Gaussian	0.005 0.02 0.05 0.1 0.2	29.4083 23.6304 19.8560 17.1360 14.6560	31.1889 17.0526 22.6613 19.9780 17.6355
Gaussian + CLAHE	0.005 0.02 0.05 0.1 0.2	19.1026 17.9945 16.5062 15.0272 13.5813	18.0191 16.7286 15.5654 14.7609 14.2514

Table 1: PSNR (in dB) values for different filters with CLAHE against different attacks or noises at different noise variances.

Observation- From the table it is clear that for noise variance of 0.005,0.05,0.02 median ad mean filters give acceptable results.Gaussian filter removes less noise comparing to mean and median filter for salt noise The filtering technique with enhancement has decrease the PSNR value which may be because here the enhancement is done for each individual color space and merge together for getting the filtered enhanced image which also has enhanced the noise component.This can be overcome by tuning clipping limit to a proper value by varying it and enhancing the image by converting it into LAB space and enhancing only the Luminance component.