Improved Image Quality Retinal Fundus with Contrast Limited Adaptive Histogram Equalization and Filter Variation

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***Abstract*— The use of retinal fundus images in the detection and initial diagnosis of abnormalities or diseases in the retina at this time has become one of the areas of interest to researchers, but these fundus images sometimes have low quality. Therefore, the quality of the fundus image must be improved first in order to facilitate the next process and obtain accurate results. In this study, we used the Contrast Limited Adaptive Histogram Equalization (CLAHE) method with filter order statistics, median filters, Gaussian filters, and Wiener filters using the STARE dataset to improve the quality of retinal images. In this paper, we use Mean Square Error (MSE) and Peak Signal Noise to Ratio (PSNR) as parameters for comparison between methods. From the several methods used, the lowest MSE value is 12.668 which is the result of the Order Statistical Filter and Gaussian Noise method, while the highest PSNR value is 46.58359 dB which is the result of CLAHE and Median Filter.**

***Keywords*— Enhancement, CLAHE, Median Filter, Wiener Filter, Gaussian Filter.**

I. INTRODUCTION

The retina is the deepest layer of the eyeball in the form of a very thin membrane, where the retina is very sensitive to light. The retina can function as a shaper and then is continued by nerves to the brain. Retina can experience abnormalities, retinal abnormalities are a disorder in the retina in the eye which has a bad influence on human vision. Abnormalities in the retina can cause visual disturbances to experience blindness in humans. Abnormalities in the retina can be seen in the eyes such as the widening of the retinal blood vessels, bleeding in the retina, changes in the macula, and other tissues in the retina.

In the medical world today, retinal fundus images are widely used in clinical diagnoses to detect retinal disorders [1]. Retinal fundus image is one medical image obtained through fundus photography using a fundus camera. Fundus cameras are used to retrieve features such as the retina, optical disc area and glass area, posterior surface of the eye and macula area [1] [2]. Retinal images produced through fundal cameras often have lower contrast intensity. The causes of low image quality include movement of objects, limited medical equipment [3], uneven light intensity [4], blurring, sensor systems that lack focus, noise disturbances in sensors and electronic devices, and low contrast [5].

At present, improving medical images is used to diagnose diseases and is one of the areas of interest to researchers and doctors. Increased retinal image used in the application of retinal disease as a preprocessing technique [6]. The increased retinal image is not only used for the classification of diseases but also for classification of diseases as an initial or critical stage. Main Goals Improve medical image. An improved medical image that can distinguish ships from the background, especially for very small vessels. Because blood vessels are one of the important information in the fundus image. However, it is sensitive to noise [3].

The method in the previous study was proposed to eliminate the problem in the retinal fundus image. One of them, in the study [4] used image contrast enhancement techniques based on the Independent Component Analysis (ICA2) architecture in overcoming the problem of contrast and the adverse effects on the correct image segmentation. In the study [3], compiled a method of increasing retinal vessels with morphological filters and combining of Gabor and matched filters to eliminate noise from poor quality images and low contrast. In the study [7], increasing vessels using a frangi filter helped the segmentation process distinguish large vessels and small vessels. In the study [8], proposed a method of increasing vessels to differentiate vessel size for the segmentation process

In this study we compared several methods to improve low image quality using the CLAHE method by adding several different filters, to compare and see methods that improve the image better.

II. RELATED WORK

Retinal fundus image enhancement is not easy to do because of imperfect imaging processes such as unbalanced lighting, low contrast retinal image quality which results in facilitating information and features for the purpose of diagnosing diseases in retinal delivery.

Therefore, image problems need to be addressed. Retina. Some researchers have conducted research. In the study [1] to eliminate noise and increase the contrast of retinal fundus images using the CLAHE method. A method that can be proven to be effective by using various performance and quality parameters such as Peak Signal to Noise Ratio (PSNR), Structural Similarity Index (SSIM), Correlation Coefficient (CoC) and Edge Preservation Index (EPI). With results of 7.85% Increase in PSNR, 1.19% Increase in SSIM, 0.12% Increase in CoC and 1.28% Increase in EPI.

In the study [3] used the method of increasing the ship to change the contrast and the images escaped based on mathematical morphology, multi-scales changed the morphological bottom-hat and Gabor combinations and matching filters. The proposed method increases the CH value from 1.25 from the original image to 4.70, which is much higher than the multi-scale morphological bottom-hat transformation (1.59), Gabor filter (1.91) and matching filters (2.44). In the study [9] used the transformation method of bowler-hat based on mathematical morphology to overcome quality problems in retinal blood vessel imagery and proved to be able to connect blood vessels to remain strong in conversion.

In the study [5], the authors proposed a method for achieving superior image enhancement and maintaining naturalness images. This method increases Luminosity and improves image quality with CLAHE. The results were analyzed and validated in their exclusive dataset of 961 retinal color images and then on the Messidor dataset. This method is superior in the L * a * b color space compared to Hue, Saturation, and Value (HSV) and Hue, Saturation, Lightness (HLS) color spaces. This method works better on their exclusive retinal dataset. Meanwhile, the Messidor dataset is slightly better than the general one.

In the study [10], using the Normalization Convolution method with the Domain Transform and Noise Removal to improve image quality and increase retinal vessels. This study uses a DRIVE, STARE, and DIARETDB1 dataset. Results Improved images of the proposed method are color images. Because the green channel image is used then, only the green channel image of the elevated image is used for the assessment. This method produces images that improve that is good. However, this method takes longer than other methods of removing noise

In the study [11], this study sought to solve the problem of noise in retinal images, giving rise to differences in contrast and low contrast in image enhancement. This study compares the Time Domain Constraint Estimator (TDCE) method with filter methods such as Least Square Estimator (LSE), Wiener filter, Minimum Variance Estimator (MVE) and Stationary Wavelet Transform (SWT) in the image of the green saline retina. The approved method is better for noise removal based on the PSNR value. Using the FINDeRS dataset consisting of 175 images. This study shows weaknesses in Wiener and SWT filters which cause images to be indistinguishable from very small colors with backgrounds.

III. LIRETATURE REVIEW

A. *Morphology Filter*

Morphology Filter is a structural element of an image defined by three-dimensional functions, namely F (x, y) and K. Morphology filter has six basic gray-scale morphological operations namely Dilation, Erosion, Opening, Closing, Top-hat, and Bottom- Hat defined as follows:

Dilation:

$$\in_K(F) = \max_{a,b\in K} \{F_{(m+a,n+b)} + K_{(a,b)}\} \tag{1}$$

Erosion:

$$\delta_K(F) = \min_{a,b\in K}\{F_{(m-a,n-b)} - K_{(a,b)}\} \tag{2}$$

Opening:

$$\gamma_K(F) = \in_K(\gamma_K(F)) \tag{3}$$

Closing:

$$\phi_K(F) = \delta_K(\in_K(F)) \tag{4}$$

Top-hat:

$$TH = F - \gamma_K(F) \tag{5}$$

Bottom-hat:

$$BH = \phi_K(F) - F \tag{6}$$

Dilation surgery uses bright areas and removes areas in the image. Restoring, erosion operations are carried out as the area darkens and reduces light. The opening operation to maintain (thinning) the pattern of a darker area (brighter) in the surrounding environment, while the closure operation works to maintain (thinning) the published light and fold pattern. Top-hat and Bottom-Hat to extract bright and black patterns from certain structures of an image [3].

B. *Contrast Limited Adaptive Histogram Equalization* (CLAHE)

CLAHE is a method used in contrast enhancement on low contrast problems found in digital images such as medical images. CLAHE is the development of the Adaptive Histogram Equalization (AHE) and Histogram Equalization (HE) methods that use probability theory on a grayscale to improve and solve the problem of comparison for digital images. CLAHE performs the operation by increasing Complications [7] carried out by Histogram Equalization (HE), the results of improvements obtained in medical images are even better by increasing Compensation in HE.

Increased contrast can be selected as the slope of the function that has a relationship in the increase, the input value, and the desired input image. The slope of the function can also be improved in contrast enhancement controls. In this CLAHE process, the retinal fundus image is processed by a petch to have a better contrast of fundal images [1].

C. *Noise Removing*

Noise is a problem with unwanted images. Noise can be generated compilation in the image acquisition process and also produced by the image processing itself as a contrast enhancement [12]. Various filters can be done for noise removal such as median filters, Wiener filters, etc.

1. Gaussian Filter

Gaussian Filter is a linear filter with a weighting value for each member. The Gaussian filter works to reduce noise in the image. The way the Gaussian works is to remove the high-frequency component from the image so that the Gaussian technique is accepted as a low-pass filter. The Gaussian filter uses the Gaussian distribution function. The image equation shows the Gaussian distribution function for two-dimensional space. Then the Gaussian filter is generally presented in the form of a two-dimensional array at [x, y]. The Gaussian filter is written in comparison as follows.

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

a. G (x,y) is an element of the Gauss matrix at position [x, y].

b. σ is a standard deviation or sigma.

c. x,y is the size of the Gauss matrix which places the points x to + x, and the middle points are at x = 0 and y = 0.

2. Median Filter

Median Filter is one technique to improve image quality in the spatial domain. This method is included in the category of non-linear filters which are quite popular, in median image processing, making archives to eliminate noise and smooth the image. This method works by sorting or sorting the values of pixels in one window upward. After the value is sorted, the median value will be searched, the median value obtained will be obtained the original pixel value at the center of the window field [13]. If the sequence of pixels is an even number, the average of the two middle pixel values is calculated and used [14]. Mathematically the median filter can be formulated as equation 2.8 below:

$$\hat{f}(x,y) = median\,\{\,g(r,c)\mid(r,c)\,\epsilon\,W\,\} \qquad (8)$$

The median filter takes a certain area of the image according to the specified kernel (mask) size (generally 3 × 3) but can be used using a larger size, then looks at each pixel value in that area, and the middle value in the area is replaced by a value median. The median filter works well in terms of increasing the fundus image [1].

3. Wiener Filter

Wiener filter is a linear image restoration approach that operates on the principle of least squares. The wiener filter equation in the frequency domain is:

$$X(i,j) \approx \left[\frac{1}{F(i,j)}\frac{|F(i,j)|^2}{|F(i,j)|^2+K}\right]Y(i,j) \qquad (9)$$

K is a constant commonly used to approximate noise intensity. Can be selected interactively to get the best results.

4. Order Statistical Filter

The Order Statistics Filter, in general, is a nonlinear spatial filter that is generated based on the sequence (rank) of pixels that fill the area of the image flanked by the filter and then change the value of the pixel center with the value determined by the ranking results. Some of the Statistical Order Filters used are Median Filters which are useful for selecting the middle value.

Order Statistics Filters are non-linear filters which are one method for reducing noise, which consists of the Median Filter, Mean Filter, Max Filter, Min Filter, and Midpoint Filter. With the Order Statistic Filters, method built a filtering application that is used to reduce Salt-pepper noise or Gaussian Noise. The results of the implementation using the Median Filter technique can reduce Salt and pepper noise better than other filter techniques in Order Statistic Filters.

D. Noise

1. Gaussian

The Gaussian Noise is usually called White noise because all the spectral frequencies are white light. The magnitude that determines the noise is determined by the average value (average) and the value of variation (variation). The value can be positive or negative. For the default value, the mean (value) is 0 and for the variation (variance) the default value is 0.01. The greater the average value (average) and variation (variance), the noise image results will increase and it is increasingly difficult to be warned.

Averages and variations are real constants. The value can be positive but negative. The greater the average and the variation, the image will be increasingly blurred, on the contrary, the smaller the constant the effect on the image will be less visible. The default value is 0 for the mean and 0.01 for the variance. It is called white noise when the average value and its variation.

2. Salt and Pepper Noise

As the name suggests, this type of noise looks like salt and pepper. The image will look like dots. For RGB images dots appear in three colors, namely red (red), green (green) and blue (blue), while in GRAY noise images will appear in two colors namely black (black) and white (white). This noise gives the effect of "on and off" on the pixel. Constants in the form of non-negative numeric numbers ranging from 0 to 1. The greater the constant the image will be increasingly blurred, on the contrary, the smaller the constant effect on the image will be less visible The default value for noise constants is 0.05.

The basic sources of this noise in digital imagery appear during image acquisition (digit acquisition) then digitize it (digitization) or transmit (transmission). The performance of the image sensor is influenced by many different factors, such as environmental conditions (bright, bright or lack of light), and the quality of the imaging sensor elements themselves. For example, obtaining an image with a Charge Coupled Device (CCD) camera, lighting level, and temperature sensor are the main factors that determine how much noise is generated in the resulting image. Corrupted images during transmission are basically caused by interference with the channel used for transmission, for example, transmission using copper channels is analogous, then digitized, the resulting image will certainly be degraded. To give a noise effect to a study in the field of a digital image, a clean image is subjected to the noise by modifying each pixel in the image through a mathematical operation. High Pass Filter.

E. *High-Pass Filter*

High Pass is a filter that passes high frequencies and lowers low frequencies. High-pass filtering is the opposite of low-pass filtering, which is a method that makes a signal or image less smooth. The method used is weakening in the frequency domain that has a low frequency.

F. PSNR (*Peak Signal Noise to Ratio)*

To find out the PSNR value from an image you must first know the image's MSE value. MSE is a measure used to accept both methods of performing or restoring images relative to supported images. The smaller the MSE value, the better the image will look.

$$MSE = \frac{1}{XY}\sum_{y=0}^{Y=1}\sum_{x=0}^{X=1}\left(\hat{y}(i,j) - y(i,j)\right)^2 \qquad (10)$$

The PSNR value is obtained from the pixel difference between the original image and the distorted image while the SNR value of all pixel values is the most appropriate maximum value [15]. PSNR determines the quality of the image that has been processed with any technique. The higher the PSNR value, the better the quality of the image. The PSNR is formulated as:

$$PSNR = 10log_{10}\frac{s^2}{MSE} \qquad (11)$$

where s = 255 for 8 bit image.

IV. METHODOLOGY

A. *Methodology*

In this paper, a framework is needed to help writers in the preparation of research and have clear steps to obtain appropriate and structured results with the research structure that has been established. The framework used is as shown in Figure 1. below this:

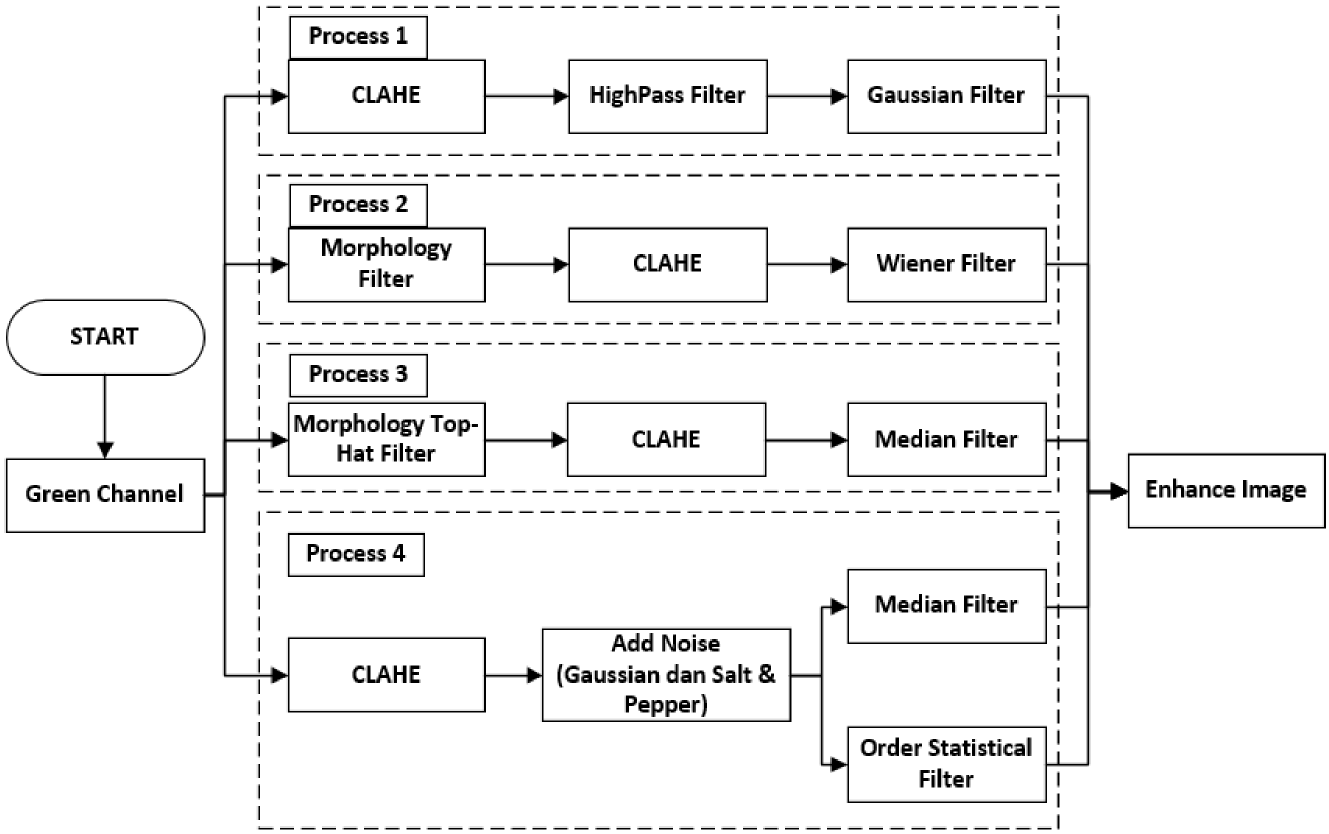


Fig. 1. Reseacrh Diagram

B. *Data Acquisition*

The dataset used is the STARE (*Structured Analysis of the Retina*) dataset which can be published in general. The Stare dataset was compiled and initiated in 1975 by Michael Goldbaum, M.D., at the University of California, San Diego. The people who contributed to this project have backgrounds ranging from medicine, science to engineering. Clinical images and data are provided by the Shiley Eye Center at the University of California, San Diego, and by the Veterans Administration Medical Center in San Diego. In the STARE dataset, there are approximately 400 retinal images in it, measuring 700 × 605 pixels in each of the images. In this study, 20 images of the retina were used. Here are some images from the STARE dataset as shown in Figure 2.

Fig. 2. STARE dataset Retina Image

C. Data Analysis

In this analysis, a calculation is made to obtain MSE and PSNR from various methods proposed by doing the results.

V. RESULLT AND DISCUSSION

In this study, we compared the results of each method using the MSE (Mean Square Error) and PSNR (Peak Signal Noise to Ratio) parameters. Where the MSE value generated can be seen in Table I, to see the PSNR value generated can be seen in Table II and in Table III can be seen the picture of the results of each process carried out in this study.

TABLE I. MSE VALUES FOR DIFFERENT ENHANCEMENT METHODS AND CLAHE FOR DIFFERENT FILTER VARIANTS

IMAGE	PROCESS I	PROSES II	PROSES III	PROCESS IV			
				MEDIAN FILTER + GAUSSIAN NOISE	MEDIAN FILTER + SALT & PEPPER NOISE	ORDER STATISTICAL FILTER + GAUSSIAN NOISE	ORDER STATISTICAL FILTER + SALT & PEPPER NOISE
Im0001	19.15	19.18	7.33	12.7	87.34	12.5	13.44
Im0002	16.31	10.23	2.03	12.8	87.45	12.46	13.36
Im0003	33.12	40.6	15.71	128	87.06	12.5	12.49
Im0004	5.98	8.03	0.44	12.7	85.96	12.32	13.36
Im0005	30.06	46.88	25.91	13.49	85.94	12.35	13.86
Im0006	7.71	7.64	1.15	13.48	84.41	13.92	13.92
Im0007	5.04	2.36	0.23	13.47	87.06	12.5	12.49
Im0008	14.73	12.83	9.42	13.49	85.96	12.32	12.32
Im0009	2.86	0.55	0.00	14.3	85.94	12.35	13.36
Im0010	8.93	2.24	0.67	14.3	84.6	13,35	13.86
Im0011	1.78	0.09	0.00	14.2	84.73	13,84	13.86
Im0012	12.52	13.42	8.46	14.9	85.94	12,92	12.93
Im0013	0.13	0.00	0.00	14.11	81.94	14,00	14.01
Im0014	18.52	19.01	9.14	14.13	86.69	13,01	13.6
Im0015	8.84	4.4	0.18	14.11	83.28	13,50	13.51
Im0016	6.39	3.04	0.31	14.7	85.05	13,17	13,61
Im0017	32.84	39.39	31.02	14.16	85.96	13,35	13.36
Im0018	80.55	161.85	135.84	14.21	85.94	13,84	13.86
Im0019	60.39	88.06	69.86	14.19	84.6	12,92	13.86
Im0020	27.80	37.03	19.03	14.24	84.73	13.46	12.93
Average	**19.6825**	**25.8415**	**16.8365**	**19.584**	**85.529**	**12.668**	**13.3884**

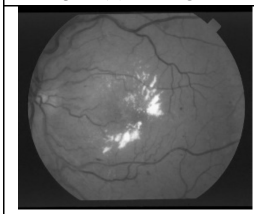
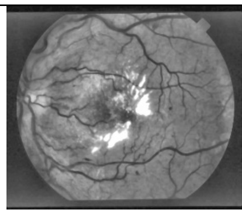
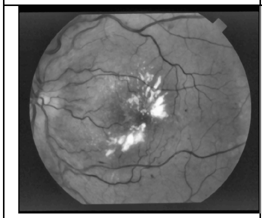
Table I. are results that involve improving the quality of the STARE dataset using the MSE parameter. Can be seen in Table I with the lowest MSE value which is equal to 12.668 which is the result of process 4 in the Filter Statistics + Gaussian Noise Order and the highest MSE value is 85.529 which is the result of process 4 in the Median Filter + Salt & Pepper Noise.

TABLE II. PSNR (DB) VALUES FOR DIFFERENT ENHANCEMENT METHODS AND CLAHE FOR DIFFERENT FILTER VARIANTS

IMAGE	PROCESS I	PROCESS II	PROCESS III	PROSES IV			
				MEDIAN FILTER + GAUSSIAN NOISE	MEDIAN FILTER + SALT & PEPPER NOISE	ORDER STATISTICAL FILTER + GAUSSIAN NOISE	ORDER STATISTICAL FILTER + SALT & PEPPER NOISE
Im0001	35.3437	35.3371	39.5167	42.96	28.87	44.32	42.3
Im0002	36.0402	38.0672	45.0827	43.7	28.83	43.56	42.17
Im0003	32.9634	32.0795	36.2034	43.69	28.76	44.18	44.2
Im0004	40.3998	39.1182	51.7036	43.77	28.82	44.5	42.9
Im0005	33.3855	31.4550	34.0306	42.73	28.82	44.5	42.3
Im0006	39.2929	39.3338	47.5586	41.79	28.88	43.89	42.22
Im0007	41.1429	44.4414	54.6273	43.69	28.76	42.23	44.2
Im0008	36.4838	37.0815	38.4259	43.77	28.82	44.18	44.5
Im0009	43.5994	50.723	74.1338	42.73	28.82	44.5	42.9
Im0010	38.6553	44.6575	49.8866	41.83	28.88	42.91	42.3
Im0011	45.6712	58.8411	74.5571	43.74	28.88	42.31	42.3
Im0012	37.1884	36.8883	38.8908	41.8	28.82	42.31	43.5
Im0013	57.1471	80.2974	74.6354	42.83	28.82	43.5	42.13
Im0014	35.4885	35.3743	38.5547	42.94	28.78	42.14	42.58
Im0015	38.6992	41.7295	55.4994	42.86	29.95	42.5	42.78
Im0016	40.1099	43.3316	53.1887	42.78	28.94	42.01	42,36
Im0017	33.0004	32.2108	33.2487	42.91	28.88	43	42.18
Im0018	29.1040	26.0735	26.8346	42.81	28.73	43.78	42.33
Im0019	30.3549	28.7169	29.7226	42.74	28.76	43.66	42.56
Im0020	33.7240	32.4796	35.3705	43.8	28.91	43.42	42.66
Average	**37.8897**	**40.41186**	**46.58359**	**42.9935**	**28.8865**	**43.37**	**42.79**

Table II. This produces results using the PSNR parameter, where the PSNR value generated by process 4 in the Median Filter + Salt & Pepper Noise is 28.8865 and the PSNR value generated by process 3 is 46.58359.

TABLE III. TABLE ENHANCE IMAGE

ORIGINAL GREEN CHANNEL IMAGE	PROCESS I	PROCESS II	PROCESS III
	 MSE = 19.15, PSNR = 35.3437	 MSE = 19.18, PSNR = 35.3371	 MSE = 7.33, PSNR = 39.5167
PROCESS IV			
MEDIAN FILTER + GAUSSIAN NOISE	MEDIAN FILTER + SALT & PEPPER NOISE	ORDER STATISTICAL FILTER + GAUSSIAN NOISE	ORDER STATISTICAL FILTER + SALT & PEPPER NOISE
 MSE = 12.7, PSNR = 42.96	 MSE = 87.34, PSNR = 28.87	 MSE = 12.5, PSNR = 44.32	 MSE = 13.44, PSNR = 42.3

In Table III. There is one picture of the results of the quality improvement process in each method used in this study.

VI. CONCLUSION

After conducting research on Retina Image Improvement using the Clahe and Median Filter methods, order statistics, Gaussian filters, and Wiener filters and using Gaussian and salt noise and paper. We can see that in process 3 is the best improvement process because it produces a lower MSE value and has a higher PSNR value compared to other processes.

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