# A Hybrid System for Enhancement Retinal Image Reduction

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***Abstract*—A retina can use for the identification of a diabetic disease or diabetic retinopathy. Therefore, retinal images can be used for the early detection of diabetic retinopathy. The retinal images were produced by a fundus camera. Sometimes, it yielded an image that has low quality. This image contains noise and low contrast. The low-quality image causes the blood vessels in the retina unable to segment properly for disease detection. To enhance the low-quality image is needed a strong system to enhance the image quality. This study introduces a hybrid system that combined contrast enhancement and noise reduction to enhance image quality. The steps of contrast enhancement were gamma correction, CLAHE, and Local Contrast to create a better image quality. The steps of noise reduction were the result of contrast enhancement that should be combined with the Median Filter and Gaussian Filter. The method of Median and Gaussian filter can be used to determine the best method that could reduce the image noise. The results showed that the MSE, PSNR, and SSIM of the Gaussian filter were higher than the Median filter result.**

***Keywords*— *Enhancement, Retina, Hybrid System, Noise, Contrast, Image***

## I. Introduction

The retina was the innermost layer of the eyeball and the beginning of the line of vision. Retinal images could provide information if there were abnormalities in the retinal blood vessels [1], [2]. Therefore, retinal images could be used as an early detection of disease. The retina was chosen for identification because it has a unique pattern of blood vessels and varies from person to person [3]. Image enhancement was an image processing step that was carried out to enhance image quality. Images that still had noise, contrast, and low lighting would be corrected. Based on the above, it was necessary to overcome this problem.

Based on the analysis of retinal images, diseases such as diabetic retinopathy can be detected [4]. Diabetic retinopathy is a side effect on the eyes of people who have diabetes. Retinopathy diabetics form when blood sugar levels are too high and can cause damage to the blood vessels in the retina which can lead to blindness[5]. The extraction of vascular tissue in the retinal image becomes a problem when used for analysis because large blood vessels are mixed with thin vessels, complex blood tissue, and uneven illumination when obtaining images due to low contrast retinal images [6] and [7]. Retinal images obtained from various camera systems still have poor noise and contrast problems. Therefore, contrast enhancement is widely used to enhance the quality of medical images and processing in low light conditions [8].

This study used a Structured Analysis of the Retina (STARE) and Digital Retinal Images for Vessel Extraction (DRIVE) datasets. The method used was hybrid system that made a combination of contrast enhancement and noise removal in the image. The contrast enhancement methods that were combined are gamma correction, CLAHE, and local contrast. The image that has been enhanced in contrast would perform with noise reduction with a median filter and a Gaussian filter. The original image which was still in RGB form. It should be converted into grayscale form. A grayscale image was applied with a gamma correction operation to make the image brighter [9]. The gamma values tested in this study were randomly selected with the low, mid, and high gamma regions. The result of the process would be applied to the CLAHE operation to flatten the histogram and increased the image contrast significantly. The image that has increased contrast was applied by local contrast surgery to thicken the outline of the retinal image blood vessels. The final step was the combination of the enhancement contrast applied with median filter and the Gaussian filter. The parameters used for measurement in this study were MSE (Mean Square Error), PSNR (Peak Signal to Noise Ratio), and SSIM (Structural Similarity Index).

## II. Related Work

Previous research conducted by [10] using raster to vector transformation and VLM using the STARE, DRIVE, and HRF datasets. The proposed method had less time complexity and was efficient than the existing method. However, there were still some problems associated with abnormal retinal images. Previous research [11] conducted research using the Adaptive Gamma Correction method which was then followed by an equalization of the histogram to increase the overall contrast of the retinal image. This study obtained the PSNR 25.79 and SSIM 0.56 results. [12] used the Gamma Correction method followed by CLAHE (Contrast Limited Adaptive Histogram Equalization) which functions to increase each contrast on the RGB color channel. The results obtained in this study are that the color contrast is too excessive and superior. [13] used a method by

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changing the RGB color space image to the LAB color space and used adaptive histogram equalization. This method aimed to enhance the quality of the degraded retinal image. However, this method could not be used for all retinal images.

Research by [14] used Mathematical Morphology, Gabor and Matched Filter methods. Multi-scale morphological top hat transformation enhanced low contrast and accentuates blood vessels in the retinal image. This study used a non-simple method and must determine the weight value for the image. [15] conducted research by optimizing the similarity metric method. This problem was a difficult and slow optimization problem, but it could be enhanced by identifying areas of interest. The algorithm could not find a solution using full-resolution imagery.

## III. Methodology

### *A. Datasets STARE and DRIVE*

STARE (Structured Analysis of the Retina) was a project that was conceived and started in 1975 by Michael Goldbaum, M.D at the University of California, San Diego. In that case, the project was funded by the US National Institutes of Health. Over its history, more than thirty people contributed to the project, with backgrounds ranging from medicine to science to engineering. Images and clinical data provided by the Shiley Eye Center at the University of California, San Diego, and by the Veterans Administration Medical Center in San Diego [16].

The photographs for the DRIVE database were obtained from a diabetic retinopathy screening program in The Netherlands. The screening population consisted of 400 diabetic subjects between 25-90 years of age. Forty photographs have been randomly selected, 33 did not show any sign of diabetic retinopathy and 7 showed signs of mild early diabetic retinopathy.

### *B. Methods*

Starting from the acquisition of the STARE and DRIVE dataset, the image obtained was in RGB format so it needed to be converted to grayscale. The grayscale image was applied with gamma correction to make the image brighter. Gamma correction was chosen because it could achieve an increase in contrast while maintaining naturalness [17]. The gamma values tested were 0.5, 1.0, and 2.2. The application of these different gamma values was to determine the best gamma value that can be used in research. The image was applied to the CLAHE operation which aimed to significantly increase the contrast and equalization of the histogram. CLAHE could significantly increase image color and contrast [18]. The image that has increased contrast was applied to local contrast operation. Local contrast aimed to thicken the line of blood vessels in the retinal image. Local contrast worked like sharpening by not losing detail because it only did it in a local area [19]. After the contrast enhancement has done, the image that still had noise was removed by comparing the median filter and the Gaussian filter to find the best filter that could be applied in this study. The proposed system process diagram was presented in Fig. 1.

After doing the color change, contrast enhancement, and noise filtering technique, the resulting image quality enhancement was obtained as the output image. The contrast-enhanced image was saved in PNG format. The final result was measured to see the performance of the method using measurement parameters MSE, PSNR, and SSIM. The measured performance results were expected to be a comparison of the proposed method with the previous methods.

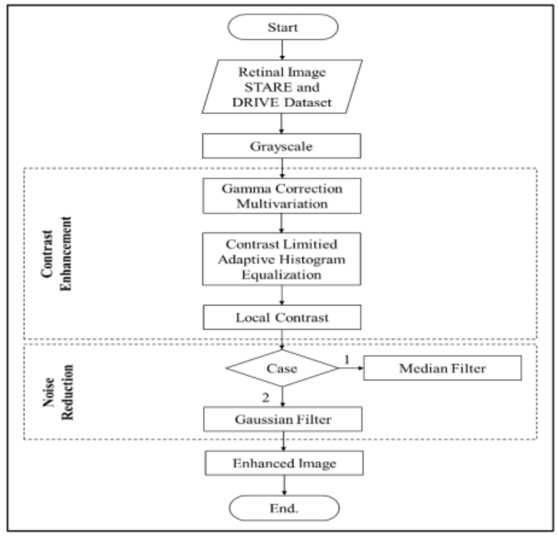



Fig. 1. Process Diagram of The Hybrid Sytem for Retinal Image Enhancement in Proposed Method

## IV. Results And Discussion

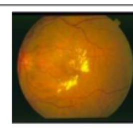
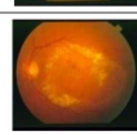
The hybrid system used in this study combined two processes for image enhancement, namely contrast enhancement and noise reduction. This hybrid system was applied to two data sets, namely STARE and DRIVE dataset. The steps taken in this hybrid system were:

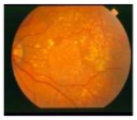
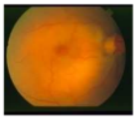
### *A. Acquisition of Datasets* STARE *and* DRIVE

In this study, the image acquisition obtained came from the Fundus STARE and DRIVE database files which were the results of the fundus camera tool in the form of fundus images and then publicized in general for analysis and research on the database on the web concerned.

The examples of the STARE and DRIVE datasets used can be presented in Table I.

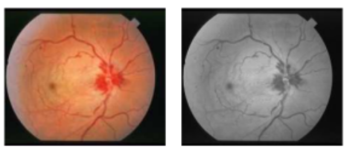
TABLE I. Examples of Tested STARE and DRIVE Datasets

| No | File Name | STARE Image | File Name | DRIVE Image |
|---|---|---|---|---|
| 1 | im0001 .ppm |  | 01_test.tif |  |
| 2 | im0002 .ppm |  | 02_test.tif |  |

| No | File Name | STARE Image | File Name | DRIVE Image |
|---|---|---|---|---|
| 3 | im0003 .ppm |  | 03_test.tif |  |
| 4 | im0004 .ppm |  | 04_test.tif |  |
| 5 | im0005 .ppm |  | 05_test.tif |  |

## *B. Contrast Enhancement*

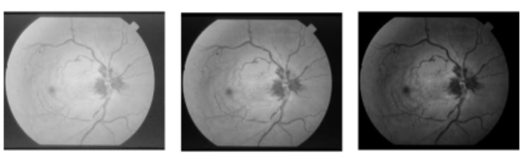
The images in the STARE and DRIVE datasets used had different intensities. The original image in the dataset was still in the form of RGB color channels, so the image needed to be converted into grayscale shape first. Some image processing algorithms could only be applied to images represented by a single matrix, so the RGB format needs to be converted. For example, the original im0005.ppm from the STARE dataset and the image that has been converted into grayscale form can be seen in Fig. 2.



(a) (b)

Fig. 2. (a) Original image and (b) Grayscale image

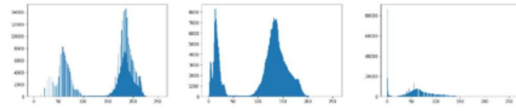
The image that has been converted into grayscale would be applied the gamma correction method so that the image became brighter. In getting the best gamma value compared to 3 values, namely 0.5; 1.0, and 2.2. The results of the application of gamma could be seen in Fig. 3.



(a) (b) (c)

Fig. 3. Gamma Correction Multivariation. (a) $\gamma$ = 0,5 (b) $\gamma$ = 1,0 (c) $\gamma$ = 2,2

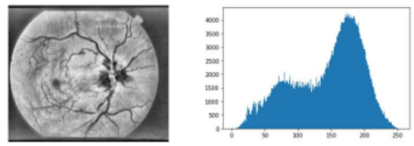
Based on Fig. 3 it can be seen that at the gamma value $\gamma = 0.5$ the image became brighter, the gamma value $\gamma = 1.0$ the image was the same as the previous grayscale image, while at the gamma value $\gamma = 2.2$ the image became darker. To determine the intensity of the gray image that has been applied gamma correction, it could be seen in the histogram Fig. 4.



(a) (b) (c)

Fig. 4. Gamma Correction Multivariation Histogram (a) $\gamma$ = 0,5 (b) $\gamma$ = 1,0 (c) $\gamma$ = 2,2

Based on the histogram in Fig. 4, it could be seen that the gray scale equalization was best at the gamma value $\gamma = 0.5$. CLAHE is required so that the contrast in the image increased significantly.



(a) (b)

Fig. 5. (a) CLAHE image and (b) CLAHE Histogram

In Fig. 5 (b) it could be seen that the contrast increased evenly after the CLAHE method. This aimed to make the lines on the blood vessels of the retina image appear thicker and have significant color contrast. Based on the parameters used, namely MSE, PSNR, and SSIM, the im0005.ppm CLAHE image get an MSE of 24.4229, PSNR of 34.2868, and SSIM of 0.5396.

Local contrast was done to clarify the edges of the blood vessels. Local contrast would increase the contrast in a smaller area while at the same time preventing global contrast enhancement thus protecting the detail of the image. The results of the local contrast image could be seen in Fig. 6.

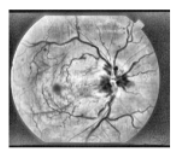


Fig. 6. Local Contrast Image

Based on the parameters used to measure the success rate of this study, the image that has been applied to local contrast get MSE of 22.5894, PSNR of 34.6258, and SSIM of 0.5035. It could be seen from these results that there is an increase in MSE and PSNR, but a decrease in the SSIM value.

If the MSE value was closer to zero, it meant the image had a good quality. If the PSNR value had a value of more than 30 dB, the image was considered to have good quality. On the other hand, the PSNR value which had a low-quality level would be close to zero. While SSIM had a value range of 0 to 1 with a value close to 0 it was said to have poor quality. SSIM values that were close to 1 were said to have good quality.

## *C. Noise Reduction*

After the contrast enhancement stage was carried out, then the noise that was still present in the retinal image was reduced. This noise reduction used a median filter and a

Gaussian filter to compare and see which filter was better to apply. At im0005.ppm, the median of MSE, PSNR, and SSIM filters was respectively 20.25, 35.09, and 0.61. Meanwhile, for the Gaussian filter, MSE, PSNR, and SSIM were respectively 20.04; 35.14, and 0.62. Based on these results, the Gaussian filter were more waiting than the median filter even though the results were not too far away.

TABLE II. THE MSE, PSNR, AND SSIM RESULTS FROM THE STARE DATASET WERE TESTED WITH DIFFERENT FILTERS (A) LOCAL CONTRAST AND MEDIAN FILTER AND (B) LOCAL CONTRAST AND GAUSSIAN FILTER

| NO | File Name | MSE | | PSNR | | SSIM | |
|---|---|---|---|---|---|---|---|
| | | *A* | *B* | *A* | *B* | *A* | *B* |
| 1 | im0001.ppm | 4.80 | 4.59 | 41.34 | 41.53 | 0.64 | 0.64 |
| 2 | im0002.ppm | 5.40 | 5.18 | 40.83 | 41.01 | 0.63 | 0.63 |
| 3 | im0003.ppm | 12.62 | 12.17 | 37.15 | 37.30 | 0.62 | 0.62 |
| 4 | im0004.ppm | 1.04 | 1.03 | 47.98 | 48.00 | 0.67 | 0.68 |
| 5 | im0005.ppm | 20.25 | 20.04 | 35.09 | 35.14 | 0.61 | 0.62 |
| 6 | im0006.ppm | 1.64 | 1.67 | 45.99 | 45.91 | 0.67 | 0.67 |
| 7 | im0007.ppm | 1.12 | 1.09 | 47.64 | 47.75 | 0.65 | 0.66 |
| 8 | im0008.ppm | 12.42 | 12.32 | 37.22 | 37.25 | 0.60 | 0.60 |
| 9 | im0009.ppm | 2.37 | 2.31 | 44.40 | 44.52 | 0.57 | 0.57 |
| 10 | im0010.ppm | 6.04 | 5.96 | 40.35 | 40.41 | 0.64 | 0.65 |
| 11 | im0011.ppm | 3.29 | 3.17 | 42.99 | 43.14 | 0.56 | 0.57 |
| 12 | im0012.ppm | 4.09 | 4.14 | 42.03 | 41.98 | 0.67 | 0.68 |
| 13 | im0013.ppm | 6.07 | 4.15 | 40.32 | 41.92 | 0.66 | 0.67 |
| 14 | im0014.ppm | 12.02 | 11.78 | 37.36 | 37.45 | 0.64 | 0.65 |
| 15 | im0015.ppm | 4.57 | 4.37 | 41.56 | 41.75 | 0.62 | 0.62 |
| 16 | im0016.ppm | 8.67 | 8.09 | 38.77 | 39.08 | 0.61 | 0.62 |
| 17 | im0017.ppm | 21.71 | 21.63 | 34.79 | 34.81 | 0.63 | 0.63 |
| 18 | im0018.ppm | 14.85 | 14.72 | 36.44 | 36.48 | **0.68** | **0.69** |
| 19 | im0019.ppm | 41.95 | 41.83 | 31.93 | 31.94 | 0.60 | 0.60 |
| 20 | im0020.ppm | 15.12 | 14.92 | 36.36 | 36.42 | 0.67 | 0.67 |
| | **Averages** | **10.00** | **9.76** | **40.03** | **40.19** | **0.63** | **0.64** |

TABLE III. THE MSE, PSNR, AND SSIM RESULTS FROM THE DRIVE DATASET WERE TESTED WITH DIFFERENT FILTERS

| NO | File | MSE | | PSNR | | SSIM | |
|---|---|---|---|---|---|---|---|
| | | *A* | *B* | *A* | *B* | *A* | *B* |
| 1 | 01_test.tif | 5.03 | 4.42 | 41.14 | 41.70 | 0.53 | 0.56 |
| 2 | 02_test.tif | 7.25 | 6.54 | 39.55 | 40.00 | 0.58 | 0.60 |
| 3 | 03_test.tif | 0.94 | 0.83 | 48.39 | 48.97 | 0.48 | 0.50 |
| 4 | 04_test.tif | 6.53 | 6.04 | 40.01 | 40.34 | 0.57 | 0.59 |
| 5 | 05_test.tif | 2.22 | 1.92 | 44.68 | 45.31 | 0.54 | 0.57 |
| 6 | 06_test.tif | 2.09 | 1.81 | 44.94 | 45.58 | 0.56 | 0.58 |
| 7 | 07_test.tif | 7.84 | 7.59 | 39.21 | 39.36 | 0.58 | 0.59 |
| 8 | 08_test.tif | 4.31 | 4.27 | 41.81 | 41.85 | 0.57 | 0.60 |
| 9 | 09_test.tif | 3.65 | 3.50 | 42.54 | 42.72 | 0.59 | 0.61 |
| 10 | 10_test.tif | 2.61 | 2.19 | 43.99 | 44.74 | 0.53 | 0.55 |
| 11 | 11_test.tif | 9.59 | 9.03 | 38.34 | 38.60 | 0.59 | 0.61 |
| 12 | 12_test.tif | 4.77 | 4.58 | 41.37 | 41.55 | 0.56 | 0.58 |
| 13 | 13_test.tif | 5.22 | 4.69 | 40.98 | 41.45 | 0.57 | 0.59 |
| 14 | 14_test.tif | 4.25 | 3.94 | 41.87 | 42.20 | 0.55 | 0.57 |
| 15 | 15_test.tif | 3.53 | 3.25 | 42.68 | 43.03 | 0.52 | 0.53 |
| 16 | 16_test.tif | 5.13 | 4.66 | 41.06 | 41.47 | 0.58 | 0.60 |
| 17 | 17_test.tif | 0.62 | 5.66 | 40.17 | 40.63 | 0.59 | 0.62 |
| 18 | 18_test.tif | 7.73 | 7.37 | 39.27 | 39.48 | 0.58 | 0.61 |
| 19 | 19_test.tif | 1.61 | 1.40 | 46.08 | 46.68 | 0.51 | 0.53 |
| 20 | 20_test.tif | 1.87 | 1.54 | 45.44 | 46.26 | 0.55 | 0.58 |
| **Average** | | **4.26** | **4.22** | **42.18** | **42.60** | **0.56** | **0.58** |

After going through various retinal image processing processes, several results were obtained from the quality enhancement of retinal images from the proposed method and the calculation of MSE, PNSR, and SSIM values from the proposed method in improving the quality of retinal images. The results of all tests with different parameters could be seen in Table II and Table III.

TABLE IV. THE MSE, PSNR, AND SSIM RESULTS FROM THE DRIVE AND STARE DATASETS WERE TESTED WITH DIFFERENT FILTERS (A) LOCAL CONTRAST AND MEDIAN FILTER AND (B) LOCAL CONTRAST AND GAUSSIAN FILTER

| Datasets | MSE | | PSNR | | SSIM | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| **STARE** | 10.00 | 9.76 | 40.03 | 40.19 | 0.63 | 0.64 |
| **DRIVE** | 4.26 | 4.22 | 42.18 | 42.60 | 0.56 | 0.58 |
| **Averages** | **7.13** | **6.99** | **41.10** | **41.39** | **0.59** | **0.61** |

Based on Tables II and III can be seen the comparison of the median filter and the Gaussian filter of each of the 20 images taken from the STARE and DRIVE dataset. These results indicate that the Gaussian filter consistently gets values higher than the 3 parameters used.

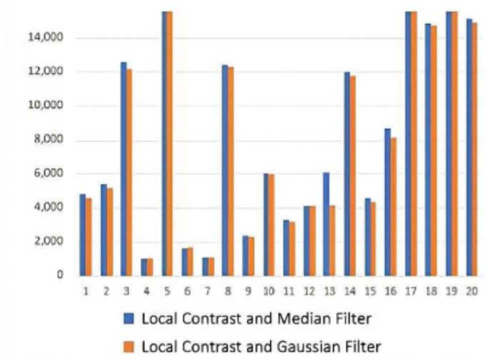



Fig. 7. Comparison Graph of MSE Median Filter and Gaussian Filter Dataset

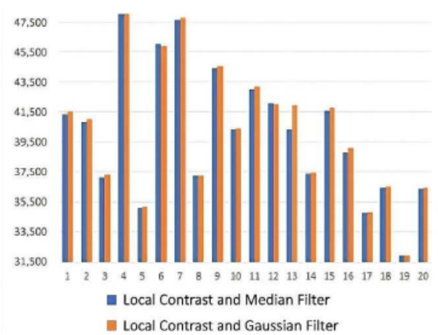



Fig. 8. Comparison Graph of PSNR Median Filter and Gaussian Filter Dataset.

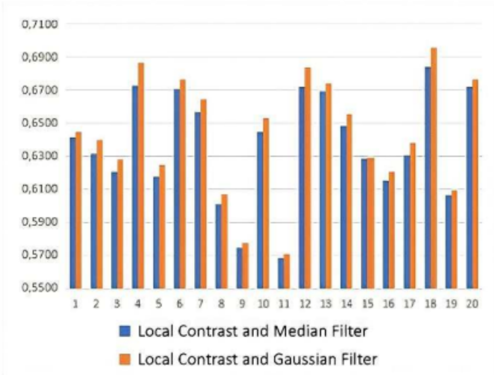



Fig. 9. Comparison Graph of SSIM Median Filter and Gaussian Filter Dataset.

Based on Fig. 7, 8, and 9 were local contrast and Gaussian filters, the results of MSE, PSNR and SSIM obtained from the results of retinal image quality enhancement using the proposed method were quite high and could assist the medical team in making an initial diagnosis of retinal image blood vessels. To see how successful this method was, the results of this study would be compared with previous studies. Comparison of research results with previous research could be seen in Table V.

TABLE V. COMPARISON OF RESULTS WITH OTHER RESEARCHERS

| Methods | MSE | PSNR (dB) | SSIM |
|---|---|---|---|
| Zhou et al, 2017 [12] (Luminosity and Contrast Adjustment) | - | 18.96 | 0.84 |
| Bataineh and Almotairi, 2021 [20] (Illumination Improvements) | - | 28.69 | 0.68 |
| Bataineh and Almotairi, 2021 [20] (CLAHE) | - | 28.42 | 0.83 |
| **Proposed Method (LC + Median Filter)** | **7.13** | **41.10** | **0.59** |
| **Proposed Method (LC + Gaussian Filter)** | **6.99** | **41.39** | **0.61** |

Based on the comparison with previous research which could be seen in Table V, Zhou et al with the luminosity and contrast adjustment methods obtained the smallest PSNR but better SSIM than proposes method, while MSE is not listed. Meanwhile, other research with CLAHE obtained an increase in PSNR to 28.42. [20] obtained a PSNR of 25.79 and an SSIM of 0.56 by using illmuniation improvements. The proposed method (LC + Gaussian Filter) got an MSE of 6.99, the best PSNR of 41.39, and an SSIM of 0.61.

The results of the application of the hybrid system showed that the combination of image enhancement using Gaussian filter noise reduction was better than the Median filter. This could be seen from the MSE, PSNR, and SSIM values generated by the Median filter and the Gaussian filter. The MSE, PSNR, and SSIM values for the Median filter were 7.13, 41.10, and 0.59. Meanwhile, the MSE, PSNR, and SSIM values for the Gaussian filter were 6.99, 41.39, and 0.61. Although the results of the two filters were not too far away, the application of the hybrid system method using a Gaussian filter for retinal image enhancement could provide image quality with better contrast enhancement and did not contain much noise.

## V. CONCLUSION

The results of image enhancement using a hybrid system that combined contrast enhancement and dimensional reduction gave good results in image enhancement. This could be seen from the results of the application of contrast enhancement Gamma Correction, CLAHE, Local Contrast, and Gaussian Filter giving brighter color to the image with the average final value of MSE, PSNR, and SSIM, namely 6.99; 41.39, and 0.61. Contrast enhancement followed by noise reduction using the Gaussian filter and Median Filter methods gave the conclusion that noise reduction could enhance the quality of the image. Of the two noise reduction methods used, the Gaussian Filter gave the higher results than the Median Filter based on the MSE, PSNR, and SSIM values obtained. Hybrid systems with Gamma Correction, CLAHE, Local Contrast, and Gaussian Filter stages could be an alternative to enhance images that have low quality so that the detection of abnormalities in retinal blood vessels could provide more accurate results.

## ACKNOWLEDGMENT

The authors thank to Direktorat Riset dan Pengabdian Masyarakat, Deputi Bidang Penguatan Riset dan Pengembangan, Kementerian Riset, Teknologi/Badan Riset dan Inovasi Nasional Republik Indonesia.

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