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Optimization of Noise Removal Techniques for Diabetic Retinopathy

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Abstract—Medical imaging is very popular research area these days and includes computer aided diagnosis of different diseases by taking digital images as input. Digital retinal images are used for the screening and diagnosis of diabetic retinopathy, an eye disease. An automated system for the diagnosis of diabetic retinopathy should highlight all signs of disease present in the image and in order to improve the accuracy of the system, the retinal image quality must be improved. In this paper, we present a method to improve the quality of input retinal image and we consider this method as a preprocessing step in automated diagnosis of diabetic retinopathy. The preprocessing consists of noise removal from retinal image. Various basic noise removal techniques such as median filter, average filter, weiner filter and FFT are evaluated for the diabetic retinopathy image database. The performance is evaluated using PSNR,RMSE and correlation of coefficient. The average filter is found to give the best performance for all diabetic retinopathy datasets under consideration.
Index Terms—diabetic retinopathy, noise removal, median filter, average filter, Weiner filter, PSNR, RMSE, correlation of coefficient

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I. INTRODUCTION

Diabetic retinopathy (DR) is a serious eye disease that occurs due to diabetes mellitus and it has grown as the most common cause of blindness in the present world. Based on latest reports by 2030 there is an epidemic rise of 4.4% in the global prevalence of diabetes [1]. Diabetic retinopathy is an asymptomatic disorder hence an effective treatment must be provided to prevent vision loss. The risk of blindness can be reduced by 50% with an early treatment to prevent the development of diabetic retinopathy [2]-[4]. Hence, the solution is to adopt a mass screening process of patients suffering from diabetes, as manual grading is resource demanding and slow. Therefore, much effort has to be made to develop a reliable computer aided diagnosis (CAD) systems purely based on color fundus images.

With a large number of patients, the workload of local ophthalmologists is highly unsubstantial. So the automated detection systems should be able to limit the severity of the disease and pave assistance to the ophthalmologists in diagnosing and remedying the disease, effectively. To build such automated systems, different modules are needed for analyzing retinal anatomical features such as fovea, optic disc, blood vessels, and common diabetic pathologies, such as hemorrhages, microaneurysms, and exudates.

In the beginning, before the detection of abnormalities and features in retinal image we must remove the noise and background from retinal image which will increase the quality of the image. This is done in preprocessing step and without this step the automated system will give poor result for feature extraction and abnormality detection. The aim of preprocessing is to increase the quality of an image by reducing the amount of noise appearing in the image and highlighting features that are used in image segmentation.

Following basic noise removal algorithms are evaluated on various iris dataset of diabetic retinopathy under consideration.

I. Median Filter
II. Average Filter
III. Weiner Filter
IV. Noise Removal by FFT and IFFT
V. The performance is evaluated using PSNR, RMSE and Correlation of coefficient. This paper is organized in four sections. Section 2 presents various techniques evaluated for noise removal. Experimental results are discussed in section 3 followed by conclusion in section 4.

II. NOISE REMOVAL TECHNIQUES

Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector [5].Image noise is generally regarded as an undesirable by-product of image capture. Although these unwanted fluctuations became known as "noise" by analogy with unwanted sound they are inaudible and such as dithering. The types of Noise are Amplifier noise (Gaussian noise), Salt-and-pepper noise, Shot noise (Poisson noise), Speckle noise.

Image de-noising is very important task in image processing for the analysis of images. Ample image de-noising algorithms are available, but the best one should remove the noise completely from the image, while preserving the details. Broadly speaking, De-noising filters can be classified in the following categories:

A. Median Filter

The median filter is a nonlinear digital filtering technique, often used to remove noise from an image or signal [6]. Such noise reduction is a typical pre-processing step to improve the results of later processing (for example, edge detection on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise (but see discussion below), also having applications in signal processing. The main idea of the median filter is to run through the signal entry by entry, replacing each entry with the median of neighboring entries. The pattern of neighbors is called the "window", which slides, entry by entry, over the entire signal [7]. For 1D signals, the most obvious window is just the first few preceding and following entries, whereas for 2D (or higher-dimensional) signals such as images, more complex window patterns are possible (such as "box" or "cross" patterns). Note that if the window has an odd number of entries, then the median is simple to define: it is just the middle value after all the entries in the window are sorted numerically[8].

B. Weiner Filter

The goal of the Wiener filter is to compute a statistical estimate of an unknown signal using a related signal as an input and filtering that known signal to produce the estimate as an output. For example, the known signal might consist of an unknown signal of interest that has been corrupted by additive noise. The Wiener filter can be used to filter out the noise from the corrupted signal to provide an estimate of the underlying signal of interest. The Wiener filter is based on a statistical approach, and a more statistical account of the theory is given in the minimum mean square error (MMSE) estimator article.

Typical deterministic filters are designed for a desired frequency response. However, the design of the Wiener filter takes a different approach. One is assumed to have knowledge of the spectral properties of the original signal and the noise, and one seeks the linear time-invariant filter whose output would come as close to the original signal as possible. Wiener filters are characterized by the following:[9]

1. Assumption: signal and (additive) noise are stationary linear stochastic processes with known spectral characteristics or known autocorrelation and cross-correlation
2. Requirement: the filter must be physically realizable/causal (this requirement can be dropped, resulting in a non-causal solution)
3. Performance criterion: minimum mean-square error (MMSE)

C. Average filter

We can use linear filtering to remove certain types of noise. Certain filters, such as averaging or Gaussian filters, are appropriate for this purpose. For example, an averaging filter is useful for removing grain noise from a photograph. Because each pixel gets set to the average of the pixels in its neighborhood, local variations caused by grain are reduced. Conventionally linear filtering Algorithms were applied for image processing. The fundamental and the simplest of these algorithms is the Mean Filter .The Mean Filter is a linear filter which uses a mask over each pixel in the signal. Each of the components of the pixels which fall under the mask are averaged together to form a single pixel. This filter is also called as average filter. The Mean Filter is poor in edge preserving. We can use linear filtering to remove certain types of noise. Certain filters, such as averaging or Gaussian filters, are appropriate for this purpose. For example, an averaging filter is useful for removing grain noise from a photograph. Because each pixel gets set to the average of the pixels in its neighborhood, local variations caused by grain are reduced.

D. Noise Removal by FFT and IFFT

First the fast Fourier transform is applied to the noise added image to transform the image from the spatial domain to frequency domain. A lowpass filter and a highpass filter are designed. Then the transformed image is filtered with lowpass filter and highpass filter. Now the inverse fast Fourier transform is employed to the lowpass filtered image and highpass filtered image. Soft thresholding is applied to the inverse of highpass image in order to enhance the sharpness of the image. The PWL filter or Lagrange or spline interpolated PWL filter is applied to the inverse of lowpass image, to enhance the smoothness of the image. Then the resulting two images are combined to retrieve the denoised image

III. IRIS DATASETS OF DAIBETIC RETINOPATHY

Table 1 lists the datasets used in this study to evaluate the performance.

Dataset Name	Number of Normal Images	Number of Diabetic Retinopathy Images	Total Images
DIARETDB0 - Standard Diabetic Retinopathy Database[9]	55	61	116
HRF Dataset[10]	15	15	30
Real Time Data from Navkar Hospital Nashik	55	79	134
DRIMDB[11]	55	125	180
Real Time Data-from Sahyadri Hospital Pune	45	46	91

Table 1: Datasets Used

IV. PERFORMANCE MEASURES

E. A. Peak signal to Noise Ratio (PSNR)

Peak signal-to-noise ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale. Although a higher PSNR generally indicates that the reconstruction is of higher quality, in some cases it may not. One has to be extremely careful with the range of validity of this metric; it is only conclusively valid when it is used to compare results from the same codec (or codec type) and same content. [12].

F. Coefficient of Correlation

A correlation coefficient is a numerical measure of some type of correlation, meaning a statistical relationship between two variables.[13] The variables may be two columns of a given data set of observations, often called a sample, or two components of a multivariate random variable with a known distribution.

Several types of correlation coefficient exist, each with their own definition and own range of usability and characteristics. They all assume values in the range from −1 to +1, where +1 indicates the strongest possible agreement and −1 the strongest possible disagreement. As tools of analysis, correlation coefficients present certain problems, including the propensity of some types to be distorted by outliers and the possibility of incorrectly being used to infer a causal relationship between the variables.[14]

G. Root Mean Square Error (RMSE)

The Root Mean Square Error (RMSE) (also called the root mean square deviation, RMSD) is a frequently used measure of the difference between values predicted by a model and the values actually observed from the environment that is being modelled. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power.

The RMSE of a model prediction with respect to the estimated variable Xmodel is defined as the square root of the mean squared error:

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(\mathrm{Xobs,i} - \mathrm{Xmodel,i})^2}{n}}$$

where Xobs is observed values and Xmodel is modelled values at time/place i.

The calculated RMSE values will have units, and RMSE for phosphorus concentrations can for this reason not be directly compared to RMSE values for chlorophyll a concentrations etc. However, the RMSE values can be used to distinguish model performance in a calibration period with that of a validation period as well as to compare the individual model performance to that of other predictive models [15].

V. PERFORMANCE EVALUATION

Following basic noise removal algorithms are evaluated on the diabetic retinopathy dataset under consideration.

i. Median Filter
ii. Average Filter
iii. Weiner Filter
iv. Noise Removal by FFT and IFFT

The performance is evaluated using PSNR, RMSE and Correlation of coefficient. Figure 1 shows the noise removal performance for the sample image from DRIONS dataset.

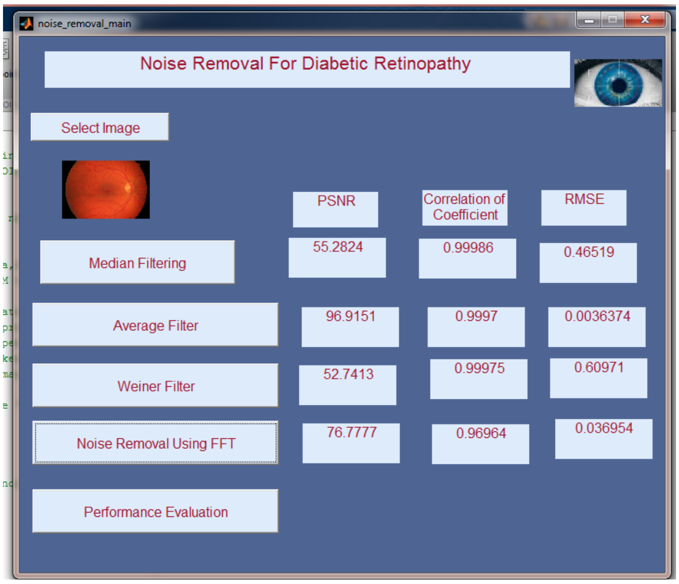

Figure 9: Performance Evaluation of Various Noise Removal Techniques

The performance of various noise removal techniques is depicted in the following tables.
Table 2 shows the performance evaluation of various noise removal techniques on DIARETDB0 - Standard Diabetic Retinopathy Database[9]

Dataset Name DIARETDB0 - Standard Diabetic Retinopathy Database	**PSNR**	**Correlation of Coefficient**	**RMSE**
Median Filtering	47.0919	0.96685	0.9584
Average Filter	**82.8572**	**0.97714**	**0.018352**
Weiner Filter	47.5992	0.99767	1.0623
Noise Removal using FFT	75.4275	0.86726	0. 043168

Table 2: Performance Evaluation on DIARETDB0 dataset

As shown in table 2, the average filter is found to give the best performance in terms of PSNR, RMSE and Correlation of Coefficient for DIARETDB0 - Standard Diabetic Retinopathy Database
Table 3 shows the performance evaluation of various noise removal techniques on HRF dataset [10]

Dataset Name HRF Database	**PSNR**	**Correlation of Coefficient**	**RMSE**
Median Filtering	51.9605	0.99976	0.67506
Average Filter	**94.4554**	**0.99959**	**0.004828**
Weiner Filter	49.5635	0.99959	0.88282
Noise Removal using FFT	75.0696	0.96548	0.040984

Table 3: Performance Evaluation on HRF dataset

As shown in table 3, the average filter is found to give the best performance in terms of PSNR, RMSE and Correlation of Coefficient for HRF Database

Table 4 shows the performance evaluation of various noise removal techniques on Real Time Data from Navkar Hospital Nashik

Dataset Name Real Time Data from Navkar Hospital Nashik	**PSNR**	**Correlation of Coefficient**	**RMSE**
Median Filtering	51.667	0.99984	0.66842
Average Filter	**95.1217**	**0.99977**	**0.0044715**
Weiner Filter	48.7511	0.99969	0.93331
Noise Removal using FFT	74.2961	0.9725	0.049174

Table 4: Performance Evaluation on Real Time Data from Navkar Hospital Nashik

As shown in table 4, the average filter is found to give the best performance in terms of PSNR, RMSE and Correlation of Coefficient on Real Time Data from Navkar Hospital Nashik

Table 5 shows the performance evaluation of various noise removal techniques on DRIMDB[11]

Dataset Name DRIMDB	**PSNR**	**Correlation of Coefficient**	**RMSE**
Median Filtering	47.9208	0.99124	1.001
Average Filter	**88.4568**	**0.98819**	**0.0096317**
Weiner Filter	45.688	0.99311	1.3327
Noise Removal using FFT	77.0055	0.81942	0.035997

Table 5: Performance Evaluation on DRIMDB dataset

As shown in table 5, the average filter is found to give the best performance in terms of PSNR, RMSE and Correlation of Coefficient on DRIMDB dataset.

Table 6 shows the performance evaluation of various noise removal techniques on Real Time Data-from Sahyadri Hospital Pune

Dataset Name Real Time Data-from Sahyadri Hospital Pune	**PSNR**	**Correlation of Coefficient**	**RMSE**
Median Filtering	50.4239	0.99954	0.77435
Average Filter	**95.0782**	**0.99942**	**0.004494**
Weiner Filter	49.4741	0.99942	0.85956
Noise Removal using FFT	75.5406	0.95304	0.04261

Table 6: Performance Evaluation on Real Time Data-from Sahyadri Hospital Pune

As shown in table 6, the average filter is found to give the best performance in terms of PSNR, RMSE and Correlation of Coefficient on Real Time Data from Sahyadri Hospital Pune

The highest value of Peak Signal to Noise Ratio and Correlation Coefficient and the low value of Root Mean Square Error show the performance of average filter to be the best amongst all noise removal techniques evaluated.

Figure 2 shows the comparison of PSNR for all the diabetic retinopathy datasets under consideration.

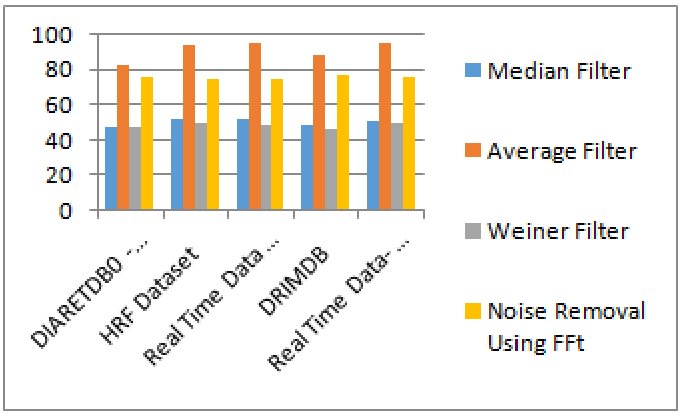

Figure 2: Comparison of PSNR

The higher value of PSNR for all diabetic retinopathy datasets under consideration, proves average filter to be the best amongst all noise removal techniques under consideration.

Figure 3 shows the comparison of Correlation of Coefficient for all the diabetic retinopathy datasets under consideration.

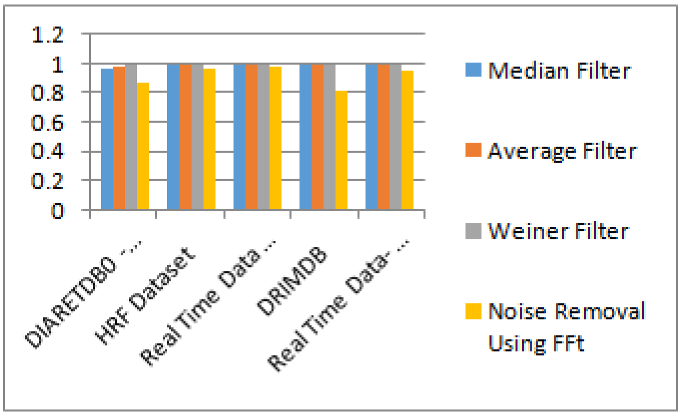

Figure 3: Comparison of Correlation of Coefficient

The higher value of Correlation of Coefficient for all diabetic retinopathy datasets under consideration, proves average filter to be the best amongst all noise removal techniques under consideration.

Figure 4 shows the comparison of RMSE for all the diabetic retinopathy datasets under consideration.

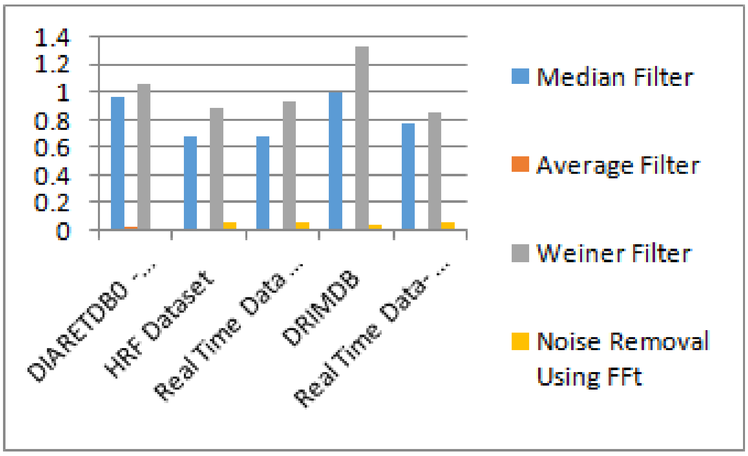

Figure 4: Comparison of RMSE

The lower value of RMSE for all diabetic retinopathy datasets under consideration, proves average filter to be the best amongst all noise removal techniques under consideration.

VI. CONCLUSION

Image Noise removal techniques are used in diabetic retinopathy to improve image quality by removing unwanted data from the image. Various image noise removal techniques are analyzed for diabetic retinopathy dataset. The performance is measured against PSNR, correlation of coefficient and RMSE. As depicted in results, average filter is proven to perform better as compared to other noise removal techniques.

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