A Comparative Study on Filters with Special Reference to Retinal Images

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ABSTRACT
Diabetic Retinopathy (DR) is one of the leading cause of blindness. Digital image processing has been effectively used for the screening, diagonosis and treatment of DR in oreder to lesser the burden of the opthamologist. The use of good quality retinal images is very essential for accurate detection, diagnosis and damage assessment of retina. Non uniform illumination and poor contrast due to the anatomy of fundus image, opaque media, and wide angle optics of the camera, insufficient pupil size, sensory array geometry, and the movement of the eye are the major causes of the low quality retinal images. This paper presents comparisons of four nonlinear de noising techniques namely: median filter, weighted median filter, adaptive median filter and decision based median filter for removal of impulse noise in retinal images. Computational work has been carried out on retinal images garnered from both hospital and publicly available DIARETDB1 dataset. The performance of these de noising filters was evaluate using Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE). Further, to asses the structural information content in such filtered images, first order entropy is estimated. The results proved that, decision based median filter emerged as an filter both in terms of high PSNR and low MSE. Added to this, the entropy signifying the retention of structured content is also at high level of 6.4 bits/pixel.

Keywords
Impulse noise, Non-linear filter, De-noising, Retinal image, Median filter, Weighted Median filter, Adaptive Median filter, Decision based Median filter, Entropy.

1. INTRODUCTION
Retinal images are used for diagnosis of various retinal diseases such as diabetic retinopathy (micro aneurysms, exudates, hemorrhages, ischemic changes), age-related macular degeneration (macular edema, cystoids macular edema), atherosclerosis, glaucoma etc. Diabetic Retinopathy is an ailment of retina caused by complications of diabetes mellitus, which can eventually lead to blindness. There are no such predominant symptoms in the early stages of diabetes, but the complications may increases in the later stages. Small changes in the retinal capillary indicate the beginning of diabetic retinopathy .Therefore to assist in the diagnosis of diabetic retinopathy, retinal images can be used as one of the developing tools. The signs of diabetic retinopathy are micro aneurysms [1-3], hemorrhages, edema [1], hard exudates and cotton wool spots [4-5]. The accuracy of all these symptoms depends on the quality of acquired retinal images. Before the detection of abnormalities and features selection in retinal images it is must to remove the different noises present in the retinal images, which will automatically increase the quality of the image.

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. Two typical techniques used in preprocessing are filtering and contrast enhancing. Contrast stretching techniques have been applied by [1], [6] and [7] for segmentation and noise reduction. In another study the local contrast enhancement method is used for equalizing uneven illumination in the intensity channel of retinal images [8]. Some times images contain uneven illumination, blurry and noisy areas. The central region of the retinal image usually contains high illumination, and the noise increases in the area closer to the edge of the retina [9]. Therefore Illumination equalization and noise removal are required to increase the quality of the image. In this paper authors have compared the performance of four nonlinear de noising techniques including median filter, weighted median filter, adaptive median filter, and decision based median filter median filter for removal of impulse noise from retinal images

This paper is organized in six sections. Section 2 presents the identification of noise type in retinal images. Section 3 describes the working of four nonlinear filters used for removal of impulse noise from retinal images. Computation work and results are discussed in section 4 followed by conclusions in section 6.

2. IDENTIFICATION OF NOISE TYPE IN RETINAL IMAGES
Noise is one of the important defects in the image that can take various forms and arises from different sources. Image noise is always random variation of brightness or color information in images. Noise is form of disturbance that may affects a signal and distorts the information carried by the signal. Noise is introduced into the image through any electrical system used for storage, transmission, and from an image acquisition process. Techniques adopted for de noising vary depending on the type of images and on the types of noise introduced or present in the image. Some of the common examples of noise are: Gaussian or White, Rayleigh, Shot, Impulse, periodic, sinusoidal or coherent, uncorrelated, and granular [11]. Retinal images are normally affected with impulse noise during image acquisition and also non uniform illumination and poor contrast due to the anatomy of fundus image, noise detection and removal is an important process as the images are corrupted by those noises because of

transmission and acquisition. Such noises negatively influence the performance of many image processing techniques. Retinal images usually have impulse noise and bad contrast degree. The advantage of the noise removal is to suppress the noise while preserving the edge information.

3. NON LINEAR FILTERS FOR DENOISING RETINAL IMAGES

Noise filtering techniques can either be linear or non-linear. The former filtering technique applies the algorithm linearly to all the pixels in the image without differentiating between the corrupted or uncorrupted pixel. Hence these filtering techniques are not effective in removing impulsive noises. In contrast, non-linear filtering technique is a two phase filtering process. In the first phase, the pixels are identified as corrupted or uncorrupted pixel and in the second phase, the corrupted pixel is filtered using the specified algorithm while the uncorrupted pixel value is retained.

(i) Median filter: The most widely used non-linear filter is the median filter which uses the median value to replace the corrupted pixel, and these filters have the capability to remove impulsive noise while preserving the edges. A In this work, Non linear filters such as median filter, adaptive median filter, weighted median filter and decision based median filter are used . A median filter smooth's the data while keeping the small and sharp details. In a median filter, a window slides across the data and the median value of the samples inside the window is chosen to be the output of the filter. The median is a stronger "central indicator" than the average. In particular, the median is hardly affected by a small number of discrepant values among the pixels in the neighborhood. Consequently, median filtering is very effective at removing various kinds of noise. This non linear filter, compared to linear ones, shows certain advantages: edge preservation and efficient noise attenuation with robustness against impulsive noise type [12]. Calculation of median value of pixel using median filter with 3x3 window is shown in figure 1.

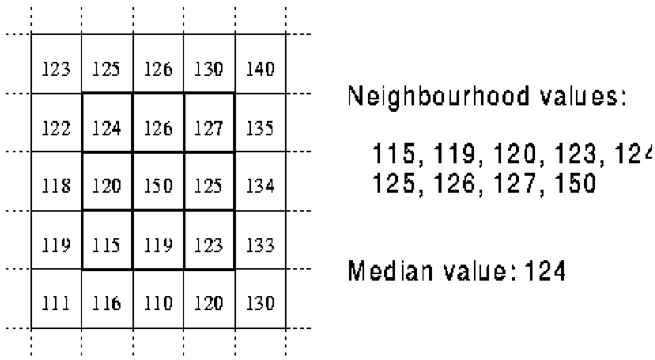

Figure 1: Calculating the median value of a pixel neighborhood

In order to explain how to perform the noise detection, we must define some parameters of image pixels. x and y represent the horizontal and vertical coordinates of a pixel respectively. p(x,y) is the pixel with coordinates x and y. g(x,y) is the gray-level of the pixel p(x,y). Sxy is the set that includes g(x,y) and its neighbor pixels. For example, a 3×3 window, Sxy = {g(x - 1,y - 1), g(x, y - 1), g(x + 1, y - 1), g(x - 1, y), g(x, y), g(x + 1, y), g(x - 1, y + 1), g(x, y + 1), g(x + 1, y + 1)}, gm is the median gray-level of the Sxy. g(x, y) represents the gray-level of the central position pixel that will be processed, (s, t) denotes the coordinates of the pixels belonging to Sxy, and g(s, t) represents the gray- level of the pixels belonging to Sxy [13].

The median filter, however, may shift the edges of objects in certain situations. Straight edges are not shifted as a result of median filtering, but curved edges are shifted inward (toward the center of the curve) and bumps tend to be smoothed out as a result. The median filter removes both the noise and the fine detail since it can't tell the difference between the two. To overcome the drawback of median filter, a median based filter called Weighted median filter is used [14, 15].

(ii) Weighted median filter: The output of weighted median filter is determined by comparing a lower and upper order statistics to the center sample in the filter window. The filtering operation of the weighted median filter is controlled with the lower and upper filter bounds which give the filter designer some freedom to determine the trade-off between noise and detail preservation. Weighted median filter is far from being a perfect filtering method since it will enhance fine details, sharp corners and thin lines for less noise. Weighted median filter does not provide good de-noising results when the noise is of 30% or more. The main reason is that the ordering process destroys any structural and spatial neighborhood information. So to overcome this drawback adaptive median filter is used.

(iii) Adaptive median filter performs well at low noise densities. But at high noise densities the window size has to be increased which may lead to blurring the image. In switching median filter, the decision is based on a pre-defined threshold value [16]. The major drawback of this method is that defining a robust decision is difficult. Also these filters will not take into account the local features as a result of which details and edges may not be recovered satisfactorily, especially when the noise level is high. To overcome the above drawback, decision based algorithm is used. In this, infrared images are de-noised by using a 3×3 window. If the processing pixel value is 0 or 255 it is processed or else it is left unchanged [17-19].

(iv) Decision based median filter, the selected 3 x 3 window elements are arranged in either increasing or decreasing order. Then the pixel values 0's and 255's in the image are removed from the image. Then the median value of the remaining pixels is taken. This median value is used to replace the noisy pixel. This filter is called trimmed median filter because the pixel values 0's and 255's are removed from the selected window. The processing pixel is checked whether it is noisy or noisy free. That is, if the processing pixel lies between maximum and minimum gray level values then it is noise free pixel, it is left unchanged. If the processing pixel takes the maximum or minimum gray level then it is noisy pixel which is processed by untrimmed decision based median filter [20, 21].

4. PERFORMANCE MEASURES

The computation work is measured using PSNR and MSE in addition to entropy measure. For the sake of completeness the performance measures are briefly discussed.

Peak Signal-to-Noise Ratio (PSNR) is the ratio between the reference signal and the distortion signal in an image, given in decibels. The higher the PSNR, the closer the distorted image is to the original. For images A = {a1 ... aM}, B = {b1 ... bM}, and MAX equal to the maximum possible pixel value (2^8 - 1 = 255 for 8-bit images):

$$PSNR(A,B) = 10\log_{10}\left(\frac{MAX^2}{MSE(A,B)}\right)$$

Mean Squared Error (MSE) is the average squared difference between a reference image and a distorted image. It is computed pixel-by-pixel by adding up the squared differences of all the pixels and dividing by the total pixel count. For images A = {a1 ... aM} and B = {b1 ... bM}, where M is the number of pixels:

$$MSE(A,B) = \frac{1}{M}\sum_{i=1}^{M}(a_i - b_i)^2 \quad (2)$$

Entropy has been applied in image processing as a measure of information. Entropy sees information as a frequency of change in the grey levels in images In addition to PSNR and MSE, Shannon's entropy has been employed to evaluating the information content of image by using equation.

$$H(X) = -\sum_{i=1}^{G} d(i)\ln_2 d(i) \quad (3)$$

Where G is the number of grey level of the image histogram ranging for a typical 8 bit image ranges between 0 to 255 and d(i) is the normalized frequency of occurrence of each grey level. To sum up the self-information of each grey level from the image, the average information content is estimated in the units of bit per pixel [22]. The entropy or average information content of the image is not affected by the image size or the pattern of grey level but by the frequency of each grey level. If the entropy of the filtered image is higher than the original image, we can conclude that the filtered image has more information than the original image

5. RESULTS

Authors have applied four nonlinear de noising filters: median filter, weighted median filter, adaptive median filter, and decision based median filter median filter for removal of impulse noise from 50 retinal images garnered from the Eye Foundation Clinic Coimbatore, India and also from the publicly available data set DIARETDB1. The size of the images was 500X752 pixel with 24 bit color were stored in tiff format files. The results are generated by using Matlab simulations. The comparisons of various filters are made based on visual appreciation and further quantitatively by Mean Square error (MSE), Peak Signal to Noise Ratio (PSNR) and entropy for different filtered images.

The visualization results of various Median, Weighted Median, Adaptive Median and Decision Based Median Filter are compared with original and noisy image as illustrated in figure 2.

Comparative performance of Median, Weighted Median, Adaptive Median and Decision Based Median Filter using PSNR is depicted in figure 3. Figure 3 clearly illustrates that among the four filters, decision based median filtering shows the best performance with highest PSNR using PSNR calculation. In addition Comparative performance of Median, Weighted Median, Adaptive Median and Decision Based Median Filter using MSE is portrayed in figure 4. Figure 4 evidently exemplifies that among the four filters, decision based median filtering shows the best performance using least MSE value.

Figure 5 highlights how the structural content of the image is retained even after applying Non-linear de noising techniques using entropy (bits/pixel) as evaluation methods. Sample of 50 images were taken in the bundle of 10. Among the four filters, Decision based median filter has shown that it is an apt method with high entropy to the tune of 6.4 bits/pixel.

6. CONCLUSIONS

Noises are unwanted information which are normally present in all type of images. It should be removed in such a way that the important information present in an image must be preserved. De-noising an image is very active research area in image processing. Identifying the noise type is the first phase in image processing for de-noising. Once the type of noise get identified respective filters are applied for de-noising, so it enhances the quality of the image and helps in future steps in processing the image for further analysis. In this study, it is found that the retinal images will contain the impulse noise. So to remove impulse noise from the retinal images, non linear filters such as median filter, weighted median filter, adaptive median filter, and decision based adaptive median filter were used. But the major drawback of standard median filter is that the filter is effective only at low noise densities. To overcome this drawback different types of median filters such as , median filter, weighed median filter, adaptive median filter, decision based adaptive median filter were employed. Decision based adaptive median filter algorithm is effective in removing salt and pepper noise from the images with high noise densities. Performance is evaluated with PSNR ,MSE and Entropy. From the computational work, it is identified that decision based adaptive median filter gives higher PSNR values and reduced MSE values and increased entropy which indicates the enhancement of the information. From this, it is evident that for the retinal images considered in this work, Decision Based Median Filter proved to be an effective one.

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8. APPENDIX

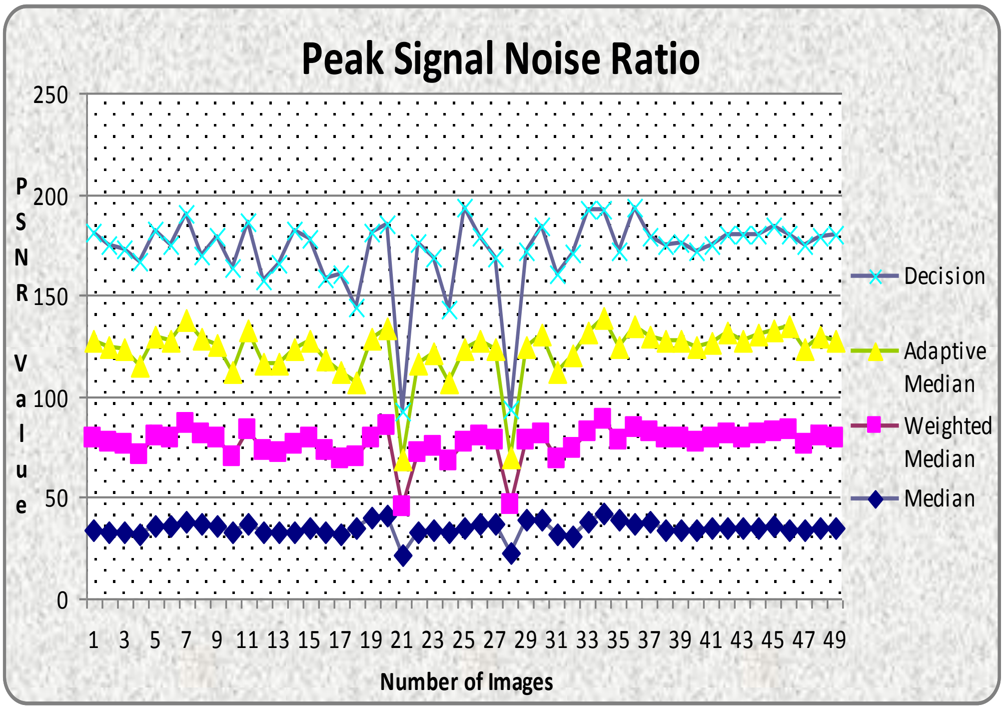

Figure 2: Simulation results of retinal image with 40% noise density (a) Original image (b) Noisy image (c) Median filter (d)Weighted Median filter (e) Adaptive Median (f)Decision Based Median Filter

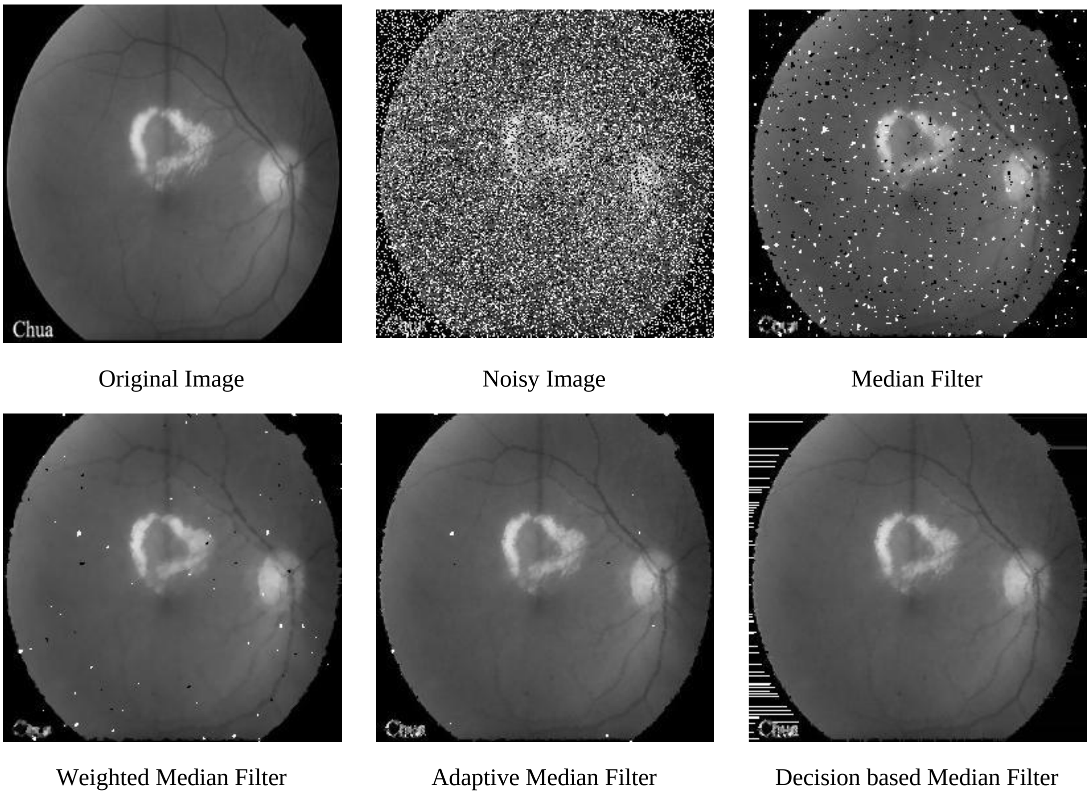

Figure 3: Performance of Median filter, Weighted Median filter, Adaptive Median filter and Decision Based Median Filter with respect to PSNR

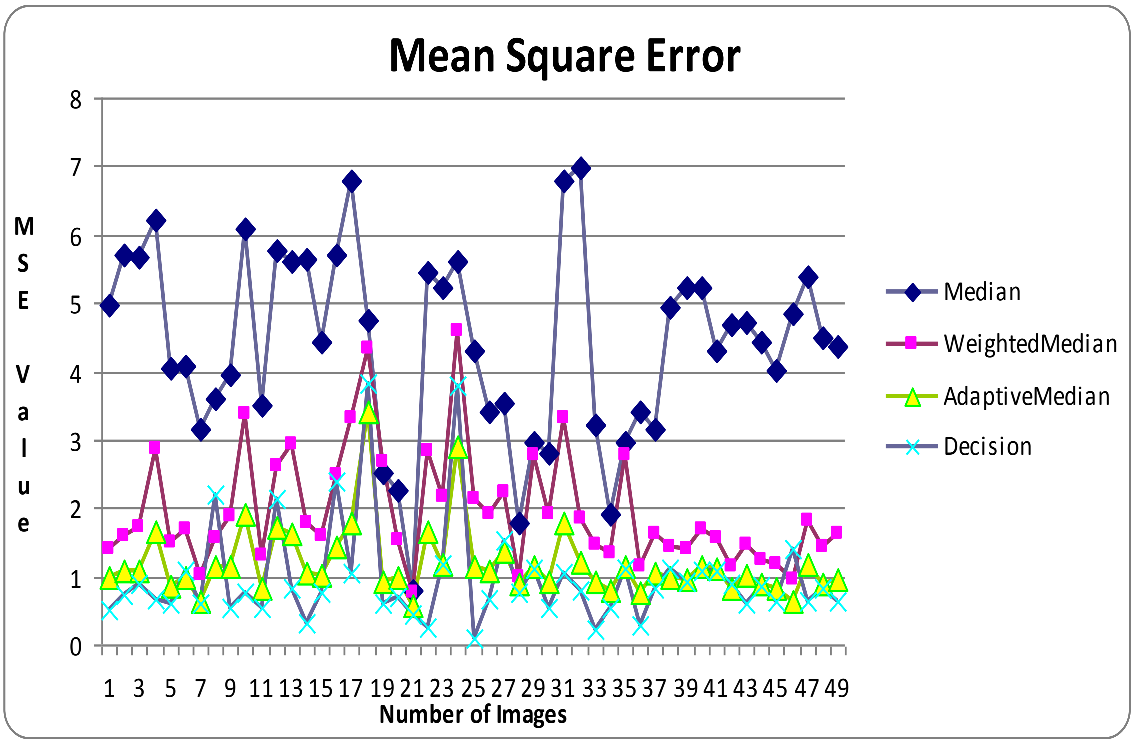

Figure 4: Performance of Median, Weighted Median , Adaptive Median and Decision Based Median Filter with respect to MSE

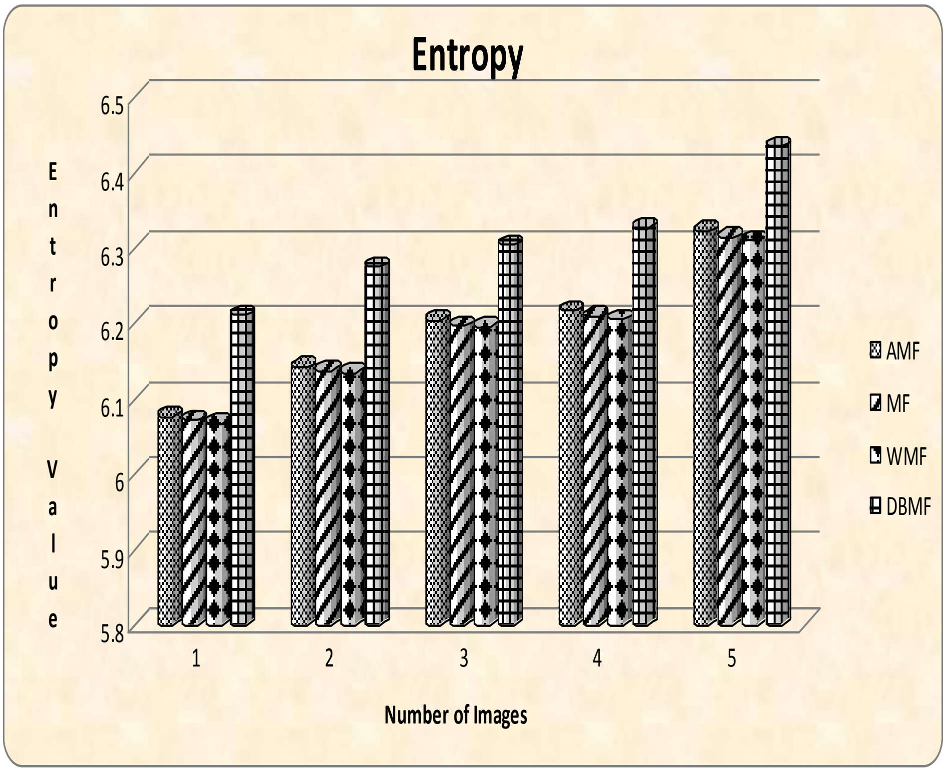

Figure 5: Performance of Median, Weighted Median, Adaptive Median and Decision Based Median Filter with respect to Entropy