A Bit Plane based Filtering Technique for Drusen in Age-related Macular Degeneration

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Abstract

Objective: The authors propose to develop a new image filter technique based on bit planes of retinal fundus image to enhance the image preprocessing task. **Method/Statistical Analysis:** The most two significant bit planes of an image are taken and preprocessed using an image matrix filter. The image arithmetic operations are used to enhance the new filter. The sample graded portions of each of the 60 AMD images are processed to study this filter technique. The effect of the technique is studied with basic statistics tests using mean, median, standard deviation and t-test, testing on column vectors of images. **Findings:** The basic statistic measures such as mean, median, range and standard deviations are applied on image pixel data before and after application of filter technique. The standard deviation of post filtered graded portions of the image shows a higher value than that of the graded portions of unfiltered image, indicating that there is a positive effect of filtering. The effectiveness of the technique is also studied with a statistical paired t-test. This test is used to find the effect of processing bit planes of the respective graded pixel portions in the image samples. This statistical evidence of the result reveal that the null hypothesis is rejected to conclude that image is enhanced for further processing of drusen spots in AMD. **Application/Improvements:** The least bit planes of the graded portions of the image may be furthur processed to enable easier classification of different types of drusens in the image.

Keywords: Age-related Macular Degeneration, Bit Plane, Drusen, Filter, Fundus Image

1. Introduction

Age-related Macular Degeneration (AMD) is a retinal disease that affects vision of people having age above 50 years[1,2]. The AMD disease is developed because of ailment factors in the retinal component called macula. The age related ailment may result in loss of central vision[3,4]. The retinal fundus images are captured and used to find the disease in the retina. Many image processing methods are developed to screen and diagnose the disorders in the human eye. Few of the major risk factors in eye disorders are found as family history, hypertension and smoking[5].

The main indicator of the disease is drusen which will appear as yellow deposits below the layer called as retinal pigment epithelium[6] in the human eye. It is easy for the ophthalmologists to control the disease if it is found at the early stage of disease progression. The number of drusen location and size contributes to the severity of the disease. Predominant symptoms of this disease are 1. Difficulty

in reading text, 2. Blurred vision, 3. Distortion vision, 4. Loss of central vision[7].

AMD is broadly categorized into two types namely dry and wet[7]. The wet type of macular disease may lead to blood bleeding because of some waste deposits below the retina to result in rapid vision loss[8,9]. The dry macular degeneration is caused by the unwanted deposits of debris in retina. Clinical studies show that most of the people are affected by this dry macular degeneration[8,9].

Stages of dry macular degenerations can appear as Early, Intermediate or Advanced forms. In the Figure 1(a) shows a fundus of a normal retina, in Figure 1(b) shows the early form, Figure 1(c) depicts the intermediate form and Figure 1(d) shows the yellow spots in advanced AMD. It is discussed that the initial form of the disease is identified with many small (63 μm in diameter) drusen or some medium sized (63 μm to 124 μm indiameter) drusen[1]. No prominent symptoms are found in this early form. The Intermediate form of macular degeneration is

identified by many medium sized drusens (also called as soft drusens). It is discussed that the symptoms of this form include blind spot, distortion of images[9]. Thirdly, the authors also discusses that the advanced form of AMD is also known as geographic atrophy that includes at least one large sized (124 μm in diameter) drusen and several medium sized drusens[1]. Few symptoms of this form include damaged photo receptor cells that senses light[9].
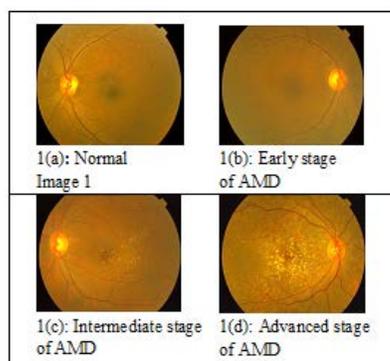
Figure 1. Normal and stages of AMD.

The authors discuss various imaging modalities including imaging in fundus, Spectral Domain OCT, Indo Cyanine Green (ICG) angiography, Fluoresce in Angiography, Thermal/Infrared (IR) imaging, Hyper spectral Retinal Imaging and fluoresce in angiogram[10]. These imaging techniques are used for detecting portions of AMD. The proposed method uses Fundus images for testing the algorithm.

Hard drusen are small lesions with sharp borders measuring 50 μm and soft drusen are those with blurry borders measuring 250 μm[10,11]. Most of the studies consent that hard drusen do not have predictable significance and however, the soft drusen is known well as an antecedent for advanced AMD conditions[10].

1.1 Classification of Drusen
A positive autocorrelation states that the neighboring areas of drusen identified have similar values[12]. A positive autocorrelation indicates that there are large lesions called soft drusen and the negative correlation identifies small lesions known as hard drusen.

A mathematical technique, Amplitude-Modulation Frequency Modulation (AM-FM) was implemented[13] to generate features for classifying the pathological drusen structure, on a retinal image. The low frequency components associate to the soft structures such as large drusen and medium frequency components

refer to the hard drusen. In the following equation, $I(k_1, k_2) = \sum_n \hat{I}_{AM,n}(k_1, k_2)\hat{I}_{FM,n}(k_1, k_2)$ the input digital image $\hat{I}(k_1, k_2)$ is defined in terms of a sum of the components of AM-FM.

1.2 Numerical Methods
The authors proposed an extended median filter algorithm to remove noise in green channel of retinal fundus images using sliding window and median value[14]. The experimental results are discussed with PSNR, MSE and RMSE. The author has applied an Adaptive median filter to resolve the non-uniform luminosities, and the image intensity is enhanced in the preprocessing stage[15]. The intensity is adjusted with an entropy based texture analysis method. In the equation $E(s) = -\sum_{i=0}^{n-1} h(s_i)\log_2 h(s_i)$,s is an arbitrary variable for intensity, $h(s_i)$ is the corresponding histogram, and n is the intensity rank of the image. The adaptive threshold was applied to a median filter to prepare for the segmentation. The morphological operators operate on the partial segmented images to detect drusen boundary, area and size. The equation $A \otimes B = \{s \,|\, (B)_s \cap A \neq \Phi\}$ refers to the dilation of A by B operation, and the equation $A \odot B = \{s \,|\, (B)_s \cap A^c = \Phi\} = 0$ refers to the erosion of A by B operation. The author has implemented a mathematical and numerical method to measure drusen. The authors demonstrated a contrast enhancement method by building a statistical model to preprocess AMD in OCT images[16].

1.3 Histogram based Techniques
The authors converse that the histogram-based image technique known as Multilevel Histogram Equalization (MLE) was used for enhancement of the image[17]. A histogram based Adaptive Local Thresholding (HALT) is another technique used to segment drusen areas, which differentiates slightly from drusen and background regions.

One of the older image processing methodologies was implemented with a preprocessing and segmentation techniques. The preprocessing tasks involve homomorphic filter, adaptive contrast enhancement filters and multilevel histogram equalization. The preprocessed image is segmented using histogram adaptive threshold, and factors with mean, median and mode measures.

Angiography images are preprocessed with a median filter and an average filter. The segmentation step includes mathematical morphology based geodesic dilation and erosion methods[11].

The author discusses a cellular neural network based algorithm for drusen identification in fundus photograph. This algorithm applies preprocessing techniques such as noise reduction, histogram normalization and segmentation technique using an adaptive method[18].

2. Materials and Methods

This section describes that data sets used for the study and the methods implemented for enhancing image restoration process.

2.1 Materials

A total of 75 fundus images were used from a private image data source. The images include, 15 normal images and 60 AMD graded images of size 768 x 576 were provided by a private clinic. The images with both soft and hard drusens were selected from the mug shot database.

2.2 Methods

The preprocess filter technique is created in MATLAB software to enhance the drusen images. The technique is proven with statistical methods to find the appropriateness of the new filtering application to drusen images.

- **Bit Plane Processing:** ABit plane is discrete signal having a collection of bits in a given bit position representing related information of an image[19]. Principally, the significant bits of the 8 bit fundus images are used for processing the vital information. Bit planes are used to analyze the relative importance of each bit in the image[18,20].

- **Filter:** In the proposed technique, a filter is created and used to process the second significant bit plane of the image. This filter technique uses a two dimensional linear filters filt1 and filt2 one after the other, which rotates the filter matrix to 180 degrees and a correlation operation, is applied to the two dimensions in the image. This operation's resultant matrix is the central portions of the correlation with the same size as that the source image. In Figure 2 shows the block diagram of the abstract version of filter algorithm technique.
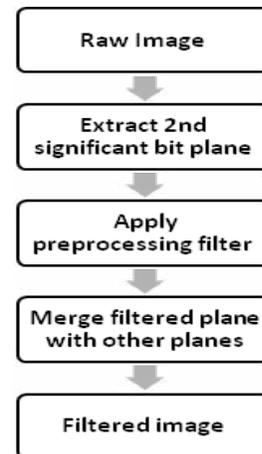

Figure 2. Block diagram of Filter technique.

Filter Technique Algorithm

- Input a two dimensional image matrix with fundus characteristics
- Apply histogram specification to perform basic preprocess
- Extract the second significant plane from the image
- Create two 2 dimensional filter elements $f1$ and $f2$
- Apply the filter elements $f1$ and $f2$ on the extracted plane to get $f1p$ and $f2p$
- Use image arithmetic on $f1p$ and $f2p$ planes to get a filtered new plane
- Merge this new plane to rest of the other planes of the image to get a filtered image

- **Image Arithmetic**

In this proposed filter technique, we use the image arithmetic to process and enhance the image to be ready for segmentation. The enhanced images are multiplied to detect the Region Of Interest (ROI) using the expression $P(x, y) = f(x, y) \times g(x, y)$, where P is the multiplied image, fandg are two filtered planes. The resultant image P has the drusen regions filtered that can be used for any further processing including segmentation and object recognition. To quantify the variation of pixel point values, the standard deviation $\sqrt{\frac{\sum (x - \bar{x})^2}{(n-1)}}$ is used to show the statistically adjusted filter operation that performs a finer. This operation creates a finer image filtering method. After application of the technique, a plot is generated with

the range of standard deviations in the y axis and column pixel values in the x axis.

3. Results and Discussion

The effect of filter processing results is discussed using two ways of statistical tests, the first with basic statistics and the second with t-test.

## 3.1 Effect of Filter Processing using basic Statistics Test

The Table 1 shows filter data of an image. The mean, median, range and standard deviations are calculated during the algorithmic phase for the images before and after application of filter technique. In the filter algorithm, after performing the plane arithmetic, a graph is plotted as shown in Figure 3(a) and 3(b).

The Figure 3(a) shows the graph plot of standard deviations of the source gray scale image. This plot shows the basic statistics calculated on each of the column pixel vectors in the image. The Table 1 shows the calculated value for Figure 3(c) alone. The table shows that the range value is calculated as 0.2541. It also shows that the mean and median values are 0.1159 and 0.09917 correspondingly. The standard deviation is calculated as 0.06264.

Table 1. basic statistical features

#	Image (Figure 3)	Mean	Median	Range	Standard Deviation
1	Before Filt Figure. (3a)	0.1159	0.09917	0.2541	0.06264
2	After Filt Figure. (3b)	0.1855	0.1513	0.323	0.08919

After application of the filter technique to the image in Figure 3(e), a graph is plotted showing the basic statistics of each of the column vector pixels in the image. In the Table 1 shows these values against after filter (After Filt) row. The table shows that the range value is calculated as 0.323. It also shows that the mean and median values are 0.1855 and 0.1513 correspondingly. The standard deviation is calculated as 0.08919.
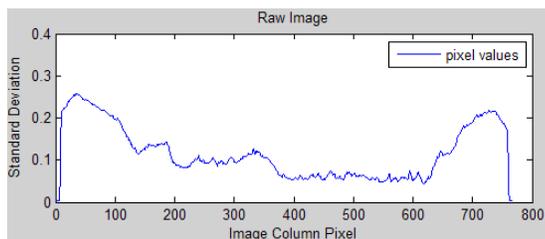
**Figure 3a.** Before Filt Image plot.
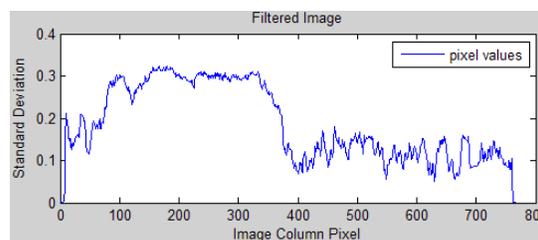
Figure 3b. After Filt Image plot.

With reference to the Table 1, it is observed that the pixel intensity (mean) of the filtered image is greater than the mean of the unfiltered image shown against before filter (Before Filt) row. Moreover, it is also observed that the standard deviation in the filtered image is more than unfiltered image. This means that there is a remarkable filtering effect by using the filter technique.

However, the disadvantage is that the optic region in the image is over filtered in the pixel column ranging from 100 to 400. The new non drusen pixel values are slightly less than the old values as shown in the four down peaks in the range from 400 to 700 in Figure 3(a). It also shows that for pixels ranging from 375 and beyond till 600, the standard deviation is increased from higher 0.07 to 0.18 approximately whereas, in Figure 3(b), the standard deviation varies from 0.05 to 0.07. Therefore, the statistical properties show that the filter has an appreciable effect on drusen fundus image and it is also proved that the required pixel data area is filtered to improve the visibility of drusens in the image.

The table shows that the standard deviation of the after filtering image (A Filt) is 0.08919 and it is greater than the deviation of the unfiltered image 0.06264.

In the Figures 4(a) and 4(c) are the two input images and Figures 4(b) and 4(d) are the two corresponding filtered images.
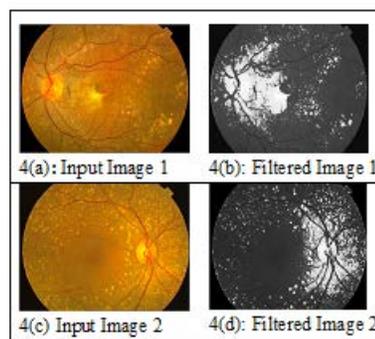
Figure 4. Input images and Filtered Images.

3.2 Effect of Filter Processing using T-Test

The effectiveness of filter processing of image with respect to unprocessed image is also studied with a t-test paired two samples for means. This test is used to find if the algorithm has an effect of processing dependency of the respective values in the sample.

The ground truth of the drusens is graded in the images and six of the graded portions are analyzed with t-test. The drusen graded portions are marked with numbers 1, 2, 3, 4, 5 and 678. The number 678 refers to the three graded portions of drusens closely located as shown (the circle mark shown in the top right corner of the image) in Figure 5. These graded portions are tested for the effective working of the filter technique. The numbered portions and the respective statistical test results are given in the Table 2.

The Table 2 shows five columns, Image Portion # refers to the portion number, No. of pixels refer to the total number of pixels in the respective portions. Each portion is created as one column vector by reshaping the m by n matrix into 1 by m x n single column matrix. This matrix is a vector with m x n matrix values. The t-Stat shows the t-Statistic calculated in the test, t2 is the t-critical two tail value and p-value is the probability of two tail value. The null hypothesis is set as 'There is no effect of the corresponding pixel filtering' on the image portion.
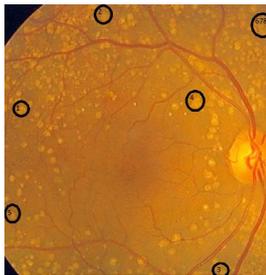

Figure 5. Drusen graded portions.

It is observed that the t-Stat value is greater than t2 and p-value<0.05 in all the six cases. Therefore, the null hypothesis is rejected and it is concluded that 'There is no effect of the corresponding pixel filtering' is rejected. That means, 'There is significant effect of the corresponding pixel filtering'. By this t-test, it is proved that the significance is more than 95%. These results firmly recommend that the application of this filter technique to the drusen portions is statistically proven.

Table 2. t-test statistical features

Image Portion #	No. of Pixels	t-Stat	t2	p-value
1	504	28.0801	1.9646	4.59E-105
2	441	32.9877	1.9653	4.94E-121
3	288	16.4160	1.9682	3.64E-43
4	650	4.5666	1.9636	5.93E-06
5	272	58.0629	1.9687	6.34-155
678	1102	31.6599	1.9621	6.05-157

4. Conclusion

The image preprocessing filter technique is applied on fundus images to suit a specific medical application. Generally, applying the right preprocessing techniques facilitate more easier classification process. This research study proved that a new filter technique specifically works good for drusens in AMD fundus images.

The unprocessed bit planes can be processed to overcome the disadvantage of over filtering the optic portion of the image. Moreover, this filter can be enhanced to filter the soft and hard drusen that will enable easier classification and segmentation of various drusen forms.

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6. References

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