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Implementation of Order Statistic Filters on Digital Image and OCT Image: A Comparative Study

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Abstract : Optical Coherence Tomography (OCT) technology introduces speckle, an insidious form of multiplicative noise which degrades the quality of OCT images. In this paper order statistics filters like Mean, Median, Min, Max and Alpha Trimmed Mean are implemented on digital image and OCT images. The images were tested with two different mask sizes of 5*5 and 7*7. The objective evaluation of both the types of images was performed using various image metrics like peak signal to noise ratio, root mean square error and image quality index. However, the existing algorithms proved to be effective for digital images and not for OCT images.

Keywords: Despeckling, Image Metrics, Optical Coherence Tomography, Order Statistics Filter, Speckle Noise.

I. Introduction

Diagnostic imaging has become a remarkable tool for medical diagnosis and disease prevention. The available technologies like Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) can provide non-invasive images of the human body. These techniques however, cannot generate high resolution images because of their physical limitations. To overcome this limitation, optical imaging has been being actively developed with the ultimate goal of high resolution ultrafast in-vivo imaging. One such technology is, Optical Coherence Tomography (OCT) a method for imaging the internal structure of biological tissue in vivo with micron resolution. OCT is based on the coherence properties of light. It enables the real-time, in situ visualization of tissue microstructure without the need to excise and process a specimen as in conventional biopsy and histopathology. One of its main limitations is the presence of speckle noise which obscures small and low-intensity features. “Coherence” in OCT technology introduces speckle, an insidious form of noise which degrades the quality of OCT images. Speckle arises as a natural consequence of the limited spatial-frequency bandwidth of the interference signals measured in optical coherence tomography (OCT) [1]. In images of highly scattering biological tissues, speckle has a dual role as a source of noise and as a carrier of information about tissue microstructure. There are different techniques developed to remove the speckle from the OCT image [2].

OCT images, as well as all other imaging modalities that involve a coherent light source, are affected by speckle noise. Speckle, arising from constructive and destructive interferences of the backscattered waves appears as a random granular pattern [1] that significantly degrades image quality and complicates further image processing tasks, like image segmentation and edge detection.

II. Mathematical Model of Speckle

Speckle is well modeled by a multiplicative noise. It is a random signal where the average amplitude increases with the overall signal intensity. It appears as bright specks in the lighter region of the image. It can be modeled as a pixel value multiplied by the random value. Speckle noise can be modeled as:

$$Y(x, y) = S(x, y).N(x, y) \qquad (1)$$

where Y, S and N represent the noisy data, signal and speckle noise, respectively. In order to change the multiplicative nature of the noise to additive one, a logarithmic transformation is applied to the image data [3]. Taking logarithm of the both sides of equation (1), leads to:

$$f(x,y) = s(x,y) + e(x,y) \qquad (2)$$

where f, s and e represent logarithms of the noisy data, signal and noise, respectively.

III. Order Statistics Filter

Order Statistics filters are nonlinear spatial filters which are based on ordering the pixels contained in an image. Usually, sliding window technique [4,5] is employed to perform pixel-by-pixel operation in a filtering algorithm. The local statistics obtained from the neighbourhood of the center pixel gives a lot of information about its expected value. If the neighbourhood data are ordered (sorted), then ordered statistical information is obtained. If this order statistics vector is applied to a finite impulse response (FIR) filter, then the overall scheme becomes an order statistics (OS) filter [1, 6]. They are differentiated based on how they choose the values in the sorted list.

Minimum and Maximum Filter

The minimum filter selects the smallest value within the pixel values and maximum filter selects the largest value within of pixel values. This is accomplished by a procedure [7] which first finds the minimum and maximum intensity values of all the pixels within a windowed region around the pixel. If the intensity of the central pixel lies within the intensity range spread of its neighbors, it is passed on to the output image unchanged. However, if the central pixel intensity is greater than the maximum value, it is set equal to the maximum value; if the central pixel intensity is less than the minimum value, it is set equal to the minimum value. The minimum and maximum filters are represented as follows:

$$\hat{f}(x,y) = \min_{(s,t)\in S_{xy}} \{g(s,t)\} \qquad (3)$$

$$\hat{f}(x,y) = \max_{(s,t)\in S_{xy}} \{g(s,t)\} \quad (4)$$

Median filter

The median filter considers each pixel in the image in turn and looks at its nearby neighbors to decide whether or not it is representative of its surroundings. Instead of simply replacing the pixel value with the mean of neighboring pixel values, it replaces it with the median of those values. The median is calculated by first sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value [6, 7]. (If the neighborhood under consideration contains an even number of pixels, the average of the two middle pixel values is used.)

$$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{median}\{g(s,t)\} \quad (5)$$

Alpha Trimmed Mean Filter

The alpha-trimmed mean (ATM) filter [4,7] is based on order statistics and varies between a median and mean filter. It is so named because, rather than averaging the entire data set, a few data points are removed (trimmed) and the remainders are averaged. The points which are removed are most extreme values, both low and high, with an equal number of points dropped at each end (symmetric trimming). In practice, the alpha-trimmed mean is computed by sorting the data low to high and summing the central part of the ordered array. The number of data values which are dropped from the average is controlled by trimming parameter alpha which is being expressed as:

$$\hat{f}(x,y) = \frac{1}{mn-d} \sum_{(s,t)\in S_{xy}} g_r(s,t) \quad (6)$$

IV. Image Metrics

The quality of an image is examined by objective evaluation as well as subjective evaluation. For subjective evaluation, the image has to be observed by a human expert. The human visual system (HVS) [8] is so complicated that it is not yet modeled properly. There are various metrics used for objective evaluation of an image. Some of them are mean squared error (MSE), root mean squared error (RMSE), and peak signal to noise ratio (PSNR) [9]. The universal image quality index (IQI) [10] is modeled by considering three different factors: (i) loss of correlation, (ii) luminance distortion and (iii) contrast distortion and they are represented as follows:

$$MSE = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N}(\hat{f}(x,y) - f(x,y)^2}{M \times N} \quad (7)$$

$$RMSE = \sqrt{MSE} \quad (8)$$

$$PSNR = 10.log_{10}(\frac{1}{MSE})db \quad (9)$$

$$IQI = \frac{\sigma_{f\hat{f}}}{\sigma_f \sigma_{\hat{f}}} \cdot \frac{2\bar{f}\bar{\hat{f}}}{(\bar{f})^2 + (\bar{\hat{f}})^2} \cdot \frac{2\sigma_f \sigma_{\hat{f}}}{\sigma_f^2 + \sigma_{\hat{f}}^2} \quad (10)$$

RESULTS

MATLAB R2009a was used to execute the existing order statistics filters like min, max, median and alpha trimmed mean filter. A mask size of 5*5 and 7*7 was used for all the filters. Fig. 1 and Fig.2 are the digital and OCT images which contain speckle noise. Fig. 3 to Fig. 10 represents the denoised digital images. Fig. 11 to Fig. 18 represents the denoised OCT images. The digital image and the OCT images that are used for the experiments are two dimensional images. Table 1 gives the comparison between the denoised digital image and the denoised OCT image through the image metrics root mean square error (RMSE), peak signal to noise ratio (PSNR) and image quality index IQI. Fig 19 shows the comparison of the order statistics filters with respect to the image metrics and it indicates that calculated RMSE values of OCT images are less when compared with digital images. However as the PSNR values for OCT images are high but the filtered OCT images are smoothened. As IQI values for the OCT images are less, it indicates that the order statistics filters reduces the contrast level of the filtered image.

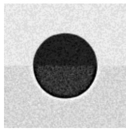

Fig. 1 Digital Image

Fig. 2 OCT Image

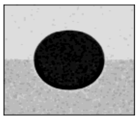

Fig. 3 min [5*5]

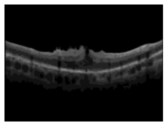

Fig. 11 min [5*5]

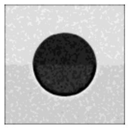

Fig. 4 max [5*5]

Fig 12. max [5*5]

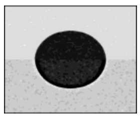

Fig. 5 median[5*5]

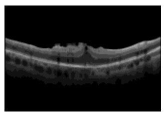

Fig. 13 median[5*5]

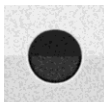

Fig. 6 ATM[5*5]

Fig. 14 ATM[5*5]

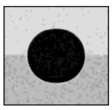

Fig. 7 min[7*7]

Fig. 15 min[7*7]

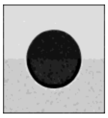

Fig. 8 max[7*7]

Fig. 16 max[7*7]

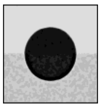

Fig. 9 median[7*7]

Fig. 17 median[7*7]

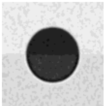

Fig. 10 ATM[7*7]

Fig. 18 ATM[7*7]

	Order Statistics Filters					
	Digital Image			OCT Image		
	RMSE	**PSNR**	**IQI**	**RMSE**	**PSNR**	**IQI**
Min [5*5]	13.435	25.57	0.8331	8.5517	29.49	0.3313
Min [7*7]	14.153	25.11	0.7839	9.0977	28.95	0.1999
Max [5*5]	8.196	29.86	0.9889	5.5468	33.25	0.4677
Max [7*7]	10.681	27.56	0.9407	7.1914	30.99	0.3478
Med [5*5]	10.362	27.82	0.952	6.8266	31.45	0.3927
Med [7*7]	12.032	26.52	0.8936	7.9139	30.16	0.3191
ATM [5*5]	15.885	24.11	0.9781	10.42	27.77	0.6394
ATM [7*7]	16.785	23.09	0.9726	11.54	25.65	0.1207

Table 1: Calculated values of image metrics like RMSE, PSNR and IQI for both digital and OCT image.

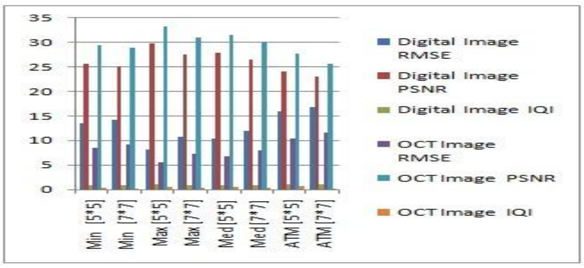

Fig. 19 Comparison between digital and OCT image.

V. Conclusion

In this work a digital image and a OCT image with speckle noise was used. The existing order statistics filters were used for removing the speckle noise. The results are evaluated through the image metrics like root mean square error, peak signal to noise ratio and image quality index. Through this work it is observed that the choice of filters for de-noising the medical images depends on the type of noise and type of filtering techniques.

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