A novel approach for noise reduction in Ultrasound images

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Abstract— Ultrasonography (US) is an important diagnosis method in medical analysis, which is further followed by certain diagnosis operations such as object recognition or feature extraction. These tasks become difficult if the images are corrupted with noises. This paper describes a technique for noise reduction in medical ultrasound (US) imaging which preserves the point and linear features. Irrespective of the post processing operation applied on US image, the image should undergo a pre processing step called denoising. The proposed algorithm first takes a decision whether the pixel under test is noise free or not, by comparing the block uniformity of N x N window with one of the entire image. Finally the noise is removed by means of weighted median filtering algorithm. Experimental results clearly indicate that the proposed method has better filtering effects than the existing standard median filter.

Keywords — US image, Noise reduction, Speckle, Impulse Noise, Alpha trimmed mean filter, Standard Median filter.

I. INTRODUCTION

In the past decades, ultrasound imaging has been considered as one of the most powerful techniques for medical imaging because of its advantages such as non-invasive property, portability, versatile nature, non usage of ionizing radiations and relatively low cost. The images obtained from commercial ultrasound systems are usually optimized for human visual interpretation. However, the usefulness of these medical US image gets degraded by signal-dependent noise called ‘speckle’, which is multiplicative in nature and noise affected while capturing images called ‘impulsive’ noise, which is additive in nature. In medical image analysis, the noise suppression is a difficult task and also needs to be taken care properly. Therefore, a tradeoff between noise reduction and the preservation of the actual image feature should be made in such a way that the diagnostic image content is enhanced. In most applications denoising the image is the fundamental process involved subsequent to image processing operations. The importance of denoising is as shown below in fig 1.

One of the common method used for denoising is the median filter, which can suppress noise with high computational efficiency. Since every pixel in the image is replaced by the median value in its neighborhood, the median filter often removes desirable details within the filtering window on the image and blurs it too. The main drawback of these filters is that median values or their variations are used to restore the noisy pixels, and hence these median based filters are alters both noise free and noisy pixels.

As a result, this performance will prone to misclassify the pixel’s characteristics.

The median based filtering operations are crucial to achieve good filtering performance, especially at high noise density interference. In order to reduce the speckle content as well as impulse noise from ultrasound images, a powerful technique for highly corrupted images called the weighted trimmed median filter for images highly corrupted with random valued impulse noise and speckle noise is proposed.[1-3]

The outline of this paper is as follows: In Section II, define the noise model. Section III describes filtering technique in detail. Section IV gives experimental results to demonstrate the performance of the proposed filtering technique. Finally conclusions are drawn in section V.

II. NOISE MODEL

Noises are basically the undesired information that degrades the image. Usually Ultrasound images are corrupted with noise modeled with either Impulse noise or speckle noise[4]. Impulse noise is caused by either malfunctioning pixels in camera sensors, faulty memory locations in hardware or erroneous transmission in a channel. Generally two types of impulse noise namely Salt & Pepper and random valued impulse noise [1] respectively. Salt & pepper noise represents the pixel value of maximum (255) and minimum (0) intensity on digital images. Whereas, in the case of random valued impulse, digital images are often corrupted by any random value in the dynamic range of grayscale. Similarly another typical noise is speckle noise, is a rough noise that naturally exists in and corrupts the quality of images. It is a type
of multiplicative and increasing noise. The proposed filter detects both the types of noise present in digital images in very efficient manner and then removes it. Noise is present in an image either in an additive or multiplicative form. An additive noise follows the rule
\[ w(x, y) = s(x, y) + n(x, y) , \]
while the multiplicative noise satisfies
\[ w(x, y) = s(x, y) \times n(x, y) , \]
where \( s(x,y) \) is the original signal, \( n(x,y) \) denotes the noise introduced into the signal to produce the corrupted image \( w(x,y) \), and \((x,y)\) represents the pixel location[5].

**Salt & pepper noise:**
Salt and pepper noise [6] is an impulse type of noise, which is also referred to as intensity spikes. This is caused generally due to errors in image capturing process or data transmission. It has only two possible values, \( a \) and \( b \). The probability of each is typically less than 0.1. The corrupted pixels are set alternatively to the minimum or to the maximum value, giving the image a “salt and pepper” like appearance. Unaffected pixels remain unchanged. For an 8-bit image, the typical value for pepper noise is 0 and for salt noise 255. The salt and pepper noise is generally caused by malfunctioning of pixel elements in the camera sensors, faulty memory locations, or timing errors in the digitization process. The probability density function for this type of noise is shown in Fig 2. Salt and pepper noise with a variance of 0.05 is shown in Fig 3.

**Speckle noise:** Speckle noise [7] is a multiplicative noise. This type of noise occurs in almost all coherent imaging systems such as laser, acoustics, ultrasound and SAR(Synthetic Aperture Radar) imagery. The source of this noise is attributed to random interference between the coherent returns. Fully developed speckle noise has the characteristic of multiplicative noise. Speckle noise follows a gamma distribution and is given as:
\[ F(g) = \frac{g^{\alpha-1} e^{-\frac{g}{\sigma}}}{(\alpha-1)\sigma^\alpha} , \]
where variance is \( \sigma^2 \alpha \) and \( g \) is the gray level. On an image, speckle noise (with variance 0.05) looks as shown in Fig4. The gamma distribution is as shown below in Fig5.

**III. FILTERING TECHNIQUE**

**Standard Median Filter (SMF):**
The Standard Median filter[8] is basically used as a preprocessing technique. Median filter have wide use in image processing to remove the noise from corrupted images, at the same time it preserves smooth edges and also useful details in the image. The basic theme of the median filter is to go through the image completely, further swapping it with the median of neighboring entries. The median filter is a dynamic filter which works like smoothers for image processing, as well as time series processing and in signal processing. A major advantage of the median filter is that it can eliminate the effect of input noise values with extremely large magnitudes. 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.
Weighted Trimmed Median Filter (WTMF):

The weighted trimmed median filter is similar to that of a standard median filter, but each of each pixel is associated with a weight function. It is one of the most important extensions of the median filter. With a proper weight set, the Weighted Trimmed Median Filter has an efficient noise suppression and an excellent image detail-preserving capability[9].

**Implementation:**

The pixels $\{I_1, I_2, \ldots, I_{m-1}, I_m, I_{m+1}, \ldots, I_y\}$ in the moving window associated with the center pixel $I_c$ must be sorted in an ascending (or descending) order, with $I_m$ being the median value. [10]. The key generalization of weighted trimmed median filter is to employ a median basket, which collects the same predetermined number of pixels above and below the median pixel. The values of these selected pixels are then averaged to give the filtering output, $A_c$, as an adjusted replacement to $I_c$, based on the following mathematical equation:

$$A_c = \frac{1}{2L+1} \sum_{j=m-L}^{m+L} I_j,$$

Where $L = \lfloor \alpha N \rfloor$, with $0 \leq \alpha \leq 0.5$. The general trimmed mean (GTM) filter uses a median basket in the same way as one does in the $\alpha$-TM filter to collect the pixels. The pixel values in the median basket and the center pixel $I_c$ in the moving window are then weighted and averaged to give the GTM filtering output:

$$G_c = \frac{\sum_{j=m-L}^{m+L} w_j I_j}{\sum_{j=m-L}^{m+L} w_j},$$

where $G_c$ is the GTM filtering output, and $w_c$ and $w_j$’s are the averaging weights for the center pixel and the pixels in the median basket, respectively. For the removal of noise, set $w_c=0$, and the varying weight trimmed median (VWTM) filter is given by

$$V_c = \frac{\sum_{j=m-L}^{m+L} w(x_{jm}) I_j}{\sum_{j=m-L}^{m+L} w(x_{jm})},$$

where $x_{jm}$ has the pixel value in the range of $[0,1]$, defined by

$$x_{jm} = \frac{|I_j - I_m|}{B},$$

With $B$ being the maximum pixel value of a given type of image (e.g., $B=255$ for an 8-bit, gray-scale image). The weight $w(x)$ is defined as a decreasing function in the range $[0, 1]$ and is chosen to be

$$w(x) = \exp\left(-A\left(\frac{x}{x-1}\right)^2\right)$$

Where, $w(0)=1$ and $w(1)=0$, so the median value always has the largest weight ($w(x_{mm})=1$). The larger the absolute difference between the pixel values in the median basket and the median value, the smaller the weight will be. The weight of the median value is the largest and the weights of other pixels in the median basket vary according to their difference from the median value. If a noise corrupted pixel happens to be selected for inclusion in the median basket, its contribution to the average will be small because $x_{jm}$ is large. In general, the weight function can assist in eliminating noise while providing a well-adjusted replacement value for the center pixel $I_c$.

**IV. EXPERIMENTAL EVALUATION**

This section describes the experimental results obtained from the proposed denoising method. All the implementation and evaluation work has been carried out in matlab 2013. The proposed method is currently applied on an ultrasound image with a resolution of 256 x 256 pixels. The performance measurement was done by calculating some image quality assurance parameters as mentioned below:

**Peak Signal to Noise Ratio (PSNR) [11,12]:**

The PSNR value is the ratio between the maximum possible power of a signal to the power of corrupting noise. Mathematically can be expressed as (in dB):

$$PSNR = 10 \log_{10} \frac{256 \times 256}{MSE}$$

**Root Mean Square Error (RMSE) [12,13]:**

RMSE is computed as the root mean square error of the corresponding pixels in the reference image $I_r$ and the final image $I_f$. The RMSE value will be zero when the reference and final images are exactly same.

$$RMSE = \sqrt{\frac{1}{MN} \sum_{x=1}^{M} \sum_{y=1}^{N} (I_r(x,y) - I_f(x,y))^2}$$

**RESULTS:**

For analysing and quantifying the performance of the filtered image parameters like PSNR and RMSE are calculated. For visualizing the defects, Figure 6 shows the input noisy image, where the information content is not clearly obtained.
The Quantitative values are presented in Table 1 along with the visual results. The metrics showed in table with bold font represent the weighted trimmed median filter and indicate to be better in comparison to the standard filters.

<table>
<thead>
<tr>
<th>FILTER</th>
<th>PSNR (dB)</th>
<th>RMSE</th>
<th>FILTERED IMAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM FILTER</td>
<td>46.36</td>
<td>15.84</td>
<td></td>
</tr>
<tr>
<td>WTM FILTER</td>
<td>7.09</td>
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</tbody>
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V. CONCLUSIONS

From the experimental and mathematical results it can be concluded that for denoising ultrasound images, the weighted trimmed median filter is optimal compared to traditional median filter. It produces the better PSNR for the output image compared to the traditional filter considered without deteriorating the image content. It is very simple, easy to implement, produces efficient noise suppression and an excellent image detail-preserving capability.

REFERENCES


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