An adaptive window hybrid median filter for despeckling of medical ultrasound images

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Speckle is a random multiplicative noise which obscures the perception and extraction of fine details in ultrasound image and despeckling is necessary for better diagnosis. The main aim of despeckling is to keep the important features such as edges of the ultrasound image. In this paper an adaptive window hybrid median filter is proposed for despeckling of medical ultrasound images. In the proposed algorithm the size of the window of the hybrid median filter is selected based on the image region and to differentiate between the smooth and edge regions it uses Sobel edge operator. A window size of 3x3 is used if the center pixel to be processed is identified as an edge pixel and in smooth regions a window size of 5x5 is used. The proposed algorithm is tested on ultrasound image of the liver and synthetically speckled image and the performance is evaluated using image quality assessment parameters Peak Signal to Noise Ratio (PSNR) and Edge Preservation Factor (EPF). The results demonstrate that the proposed algorithm reduces the speckle noise effectively and also preserves edges.

Keywords: speckle noise, despeckling, ultrasound image, hybrid median filter

Introduction

Among the medical imaging modalities currently available, ultrasound imaging systems are considered to be non-invasive, portable, and practically harmless to human body and also relatively low cost imaging modality. These features make the ultrasound imaging to be the most prevalent diagnostic tool in hospitals, but it suffers from a main disadvantage, i.e. contamination by speckle noise1, which affects all coherent imaging systems. Speckle noise significantly degrades the image quality and complicates diagnostic decisions for discriminating fine details in ultrasound images. Hence noise suppression in these images, is particularly delicate and difficult task as the speckle noise is multiplicative in nature. Segmentation of ultrasound images is also a challenging task because of speckle formation and attenuation artifacts2. Many speckle reduction methods have been proposed both in spatial and transform domain. Among them the Lee3, Kuan4 and Frost5 are the standard linear spatial filters for speckle reduction. Though these speckle reduction filters achieve good speckle suppression, the edge preserving capability is poor. A non linear filtering technique, Speckle Reducing Anisotropic Diffusion (SRAD)6 is proposed particularly for ultrasound images and is proved to have both edge preservation and enhancement capabilities. Median filtering7 is another nonlinear filtering method, used to remove the speckle noise from an ultrasound image; it replaces the original gray level of a pixel by the median of the gray values of pixels in a specific neighborhood. The hybrid median filter7, 8, 9 is windowed filter of nonlinear class, which overcomes the tendency of median and truncated median filters to erase lines which are narrower than half width of the neighborhood and round corners. In this paper an Adaptive Window Hybrid Median Filter (AWHMF) is proposed for improving the visual quality and also to preserve the fine details in the ultrasound images corrupted by speckle noise for improving the clinical diagnosis.

Experimental Section

Hybrid Median Filter

Hybrid Median Filter (HMF) is a multiple step ranking operation7,8,9 and in a 3x3 pixel neighbourhood; pixels may be ranked into two different groups3 (Fig.1). The median value of 45° neighbours forming an ‘x’ and 90° neighbours
forming a ‘+’ is compared to the central pixel and the median value of that set is then saved as the new pixel value. The same procedure is used for 5x5 pixel neighbourhood. As the hybrid median filter involves multiple ranking operations the computational complexity is less.

Proposed method
In order to preserve the features of ultrasound image, which are important for diagnosis, an Adaptive Window Hybrid Median Filter, (AWHMF) is proposed. In the proposed method, the size of the window of the HMF is selected based on the image region. Since the correlation amongst the pixels is high in the homogeneous regions, a larger window size of 5x5 is selected. On the other hand, a smaller window size of 3x3 is used for the pixel that belongs to an edge region since it has got less number of correlated pixels in its neighborhood. To differentiate between the edge and smooth region, edge detection operators are used. In the proposed algorithm Sobel operator is used for edge detection. The edge detected image is obtained by thresholding the gradient image computed using Sobel masks. As the edges are treated separately the edge preservation capability of the proposed algorithm is found to be good.

Algorithm
1. Read the noisy image.
2. Compute the edge image by applying the Sobel operator followed by thresholding and the threshold value T=100.
3. If the pixel to be processed is identified as an edge pixel then select 3x3 window size for filtering the noisy image using HMF else select 5x5 window size.
4. The denoised image is a union all the filtered pixels in step3.

Results and Discussion
Experiments are carried out to test the performance of the proposed method using both synthetically speckled image and ultrasound image of the liver. A synthetically speckled image is obtained by adding noise using imnoise command in MATLAB. The noisy image (Fig. 2b) is obtained by adding speckle noise of variance 0.02 to the original image (Fig. 2a) and the corresponding edge detected image is shown (Fig. 2b).

To assess the performance of the different despeckling techniques Peak Signal to Noise Ratio (PSNR) is used and in addition the Edge Preservation Factor (EPF) is used to test the edge preservation capability. PSNR is calculated using the equation (1)

\[ PSNR = 10 \log_{10} \left( \frac{255^2}{MSE} \right) \]  

\[ MSE = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} (x_{ij} - y_{ij})^2 \]  

Where MSE is the Mean Squared Error, M x N is the size of the image and x, y represents the original and denoised images respectively. The PSNR is higher for a better transformed image.

In ultrasound imaging in addition to speckle noise suppression, preservation of edges of the image also should be considered. So to assess the edge preservation ability of the filter, EPF is computed using (3)

\[ EPF = \frac{\sum (\Delta x - \overline{\Delta x})(\Delta y - \overline{\Delta y})}{\sqrt{\sum (\Delta x - \overline{\Delta x})^2 \sum (\Delta y - \overline{\Delta y})^2}} \]  

Where \( \Delta x \) and \( \Delta y \) are the high pass filtered version of the original image x and the denoised image y respectively. The high pass filtered version of the images is obtained by applying the Laplacian operator. The \( \overline{\Delta x} \) and \( \overline{\Delta y} \) are the mean values of the high pass filtered versions of \( \Delta x \) and \( \Delta y \) respectively.
The PSNR values of the different algorithms for synthetically speckled image by varying noise variance from 0.02 to 0.07 are plotted in Fig. 3a. The PSNR values show that the proposed algorithm outperforms other techniques in almost all levels of noise variances. Fig. 3b shows the plot of EPF values and it is seen that the proposed method consistently gives a larger value of EPF for all levels of noise variances as compared to other filters, thus indicating the edge preservation capability.

**Conclusion**

In this paper an adaptive window hybrid median filter is proposed for denoising of medical ultrasound images. The objective measures helped in assessing the performance of the proposed method against the existing filters for denoising. The experimental results for synthetically speckled image indicate that the proposed filter produces a high PSNR as compared to other filters for noise variance ranging from 0.02 to 0.07. A high value of EPF indicates the edge preservation capability is also good.

**References**