Speckle Noise Reduction with Morphological Adaptive Median Filtering Based on Edge Preservation

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ABSTRACT

Speckle noise reduction for ultrasound CT image using morphological adaptive median filtering based on edge preservation is presented in this paper. Speckle noise is multiplicative feature and causes ultrasound image to degrade widely from transducer. An input image is classified into edge region and homogeneous region in preprocessing. The speckle is reduced by morphological operation on the 2D gray scale by using convolution and correlation, and edges are preserved. The adaptive median is processed to reduce an impulse noise. As the result the proposed method enhances the image to about 20% in comparison with Winer filter by Edge Preservation Index and PSNR.

KEYWORDS

Morphological adaptive median filtering, Speckle noise reduction, Edge preservation

Ⅰ. INTRODUCTION

Ultrasound imaging have been applying to medical diagnosis widely because it is safe, practicable and convenient to evaluate and diagnose human organ in real time and at low cost in comparison with another medical diagnostic system.[1-3] However ultrasound images are accompanied with speckle nose from transducer. Speckle in ultrasound imaging makes degradation of image and interference of energy randomly due to distributed scatters. This phenomena comes from acquiring an image signal with coherent wave such as ultrasound beam, laser, microwave and radar, which is caused by coherence between reflecting and scattering at the boundary surface mainly.[4-7] The speckled image is too deceptive to diagnose and resolve. A most conventional methods for speckle nose removal has been proposed the granular pattern with gradient and symmetry, variable windowing mean filter, suppression filter, AWMF (Adaptive Weighted Median Filtering), MMSE (Minimum Mean Square Error) estimation filter, local region filter, Wavelet transform, homomorphic method, Lee and Kuan method.[6-9] In filtering for removing the speckle, the requiring edges are reduced spontaneously. It is important to preserve the edges for image enhancement.

In this paper morphological adaptive median filtering based on edge preservation will be proposed. Morphological techniques are a tool for extracting image components that are useful in the representation and description of region shape by dilation and erosion operations in an image such as boundaries. This components will preserve an edges in filtering. It has achieved great success in the applications to image restoration, noise suppressing, pattern recognition and edge extraction. The preprocessing is applied by morphological operation on the edge region and homogeneous region, and then the filtering is processed by the adaptive median interpolation with each convolutional mask. The experiment shows the comparison to the several conventional methods with Peak Signal to Noise Ratio and Edge Preservation Index for the proposed method performance.

II. EDGE PRESERVING SPECKLE REDUCTION

1. Algorithm structure

The algorithm structure is composed of 4 blocks; noise parameter calculation, region classification, morphological operation and adaptive median filtering as shown in Fig. 1. The noise parameter is calculated by speckle noise feature with variance, and that leads speckled image to calculate variance, which results in edge region and homogeneous region. The morphological operation is given by each parameter calculation. The operations take convolution and correlation, and process the adaptive median on the 2D gray scale image.

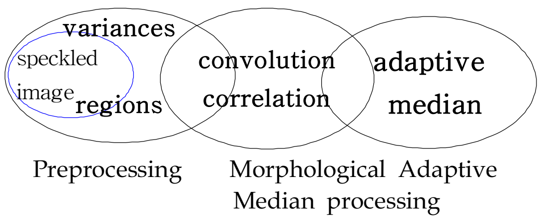


Fig. 1 Algorithm structure

2. Noise and signal variances

Generally It is difficult and deceptive to analyse and separate a speckled images because of multiplicative characteristics in ultrasound images. Speckled image signal model is given by the equation (1) with multiplicative noise and signal

$$S_{i,j} = x_{i,j} n_{i,j} \qquad i,j = 0, \dots N_1, j = 0, \dots, N_2 \quad (1)$$

where $S_{i,j}$ is image pixel included noise, $x_{i,j}$ and $n_{i,j}$ are the pixel of orignal image and speckle noise respectively. N is image size.

The noise increases in the big signal simultaneously and is dependency. That is, If mean brightness of $x_{i,j}$, increases and then noise($n_{i,j}$) grows, and vice versa. Assume that mean value of noise is E(n)=1 and stationary variance gets σ_n^2. Then, mean value of speckled image pattern($S_{i,j}$) is given by equation (2), and if noise of signal is independence, gets equation (3)

$$E(s_{i,j}) = E(x_{i,j} n_{i,j}) \qquad (2)$$

$$E(s_{i,j}) = E(x_{i,j}) \times E(n_{i,j}) = E(x_{i,j}) = b \quad (3)$$

The variance of model image is given as Eq. (4).

$$\begin{aligned} Var(s_{i,j}) &= Var(x_{i,j} \times n_{i,j}) \\ &= E[\{s_{i,j} - E(s_{i,j})\}^2] \\ &= \sigma_x^2 + \sigma_n^2 ([E(x_{i,j})]^2 + \sigma_x^2) \end{aligned} \qquad (4)$$

where the noise variance of $x_{i,j}$

$$\sigma_x^2 = \frac{\sigma_s^2 - \sigma_n^2 [E(s_{i,j})]^2}{1 + \sigma_n^2}$$

3. Morphological algorithm

The fundamental operations, dilation expands an image and erosion shrinks it. opening generally smooths the contour of an object, breaks narrow isthmuses, and eliminates thin protrusions. Closing also trends to smooth sections of contour. As opposed to opening, it generally fuses narrow breaks and long thin gulfs, eliminates small holes, and fills gaps in the contour. Erosion, dilation, opening and closing operations on 2D gray scale image are defined as the following:

Dilation: Gray scale dilation of f and b, denoted $f \oplus b$, is defined as

$$(f \oplus b)(s,t) = \max\left\{ f(s-t, t-y) + b(x,y) \;:\; (s-x),(t-y) \in D_f; (x,y) \in D_b \right\}$$

where $f(x,y)$ is the input image, $b(x,y)$ is a structuring element, D_f and D_b are the domains of f and b.

The dilation equation is similar to 2D convolution with the max operation replacing the sums of convolution and the addition replacing the products of convolution.

Erosion: Gray scale dilation of f and b, denoted $f \ominus b$, is defined as

$$(f \ominus b)(s,t) = \min\left\{ f(s+t, t+y) - b(x,y) \;:\; (s+x),(t+y) \in D_f; (x,y) \in D_b \right\}$$

The erosion equation is similar to 2D

correlation with the min operation replacing the sums of correlation and subtraction replacing the products of correlation.

Opening: $f \circ b = (f \ominus b) \oplus b$

Closing: $f \bullet b = (f \oplus b) \ominus b$

2. Adaptive Median Filtering

Median filter is nonlinear spatial filter. That response is based on ordering the pixels contained in the image area encompassed by the filter, and then replacing the value of the center pixel with the value determined by the ordering result. It provides excellent noise reduction capabilities for certain types of random noise and is particularly effective in the presence of both bipolar and unipolar impulse noise because of its appearance as white and black dots superimposed on an image. Adaptive filter changes based on statistical characteristics of the image inside the filter region defined by the $m \times n$ window area ω_{xy}. An additional benefit of the adaptive median filter is that it seeks to preserve detail while smoothing nonimpulse noise. The output of the filter is a single value used to replace the value of the pixel at (x,y), the particular point on which the window ω_{xy} is centered at a given time. Consider the notations: $\alpha_{\min}$= minimum gray level in ω_{xy}, $\alpha_{\max}$= maximum gray level value in ω_{xy}, α_{med}= median of gray levels in ω_{xy}, α_{xy}= gray level at coordinates (x,y), $\omega_{\max}$= maximum allowed size of ω_{xy}. The adaptive median filtering algorithm processes in two loops, denoted loop A and B, as follows:

Loop A:

$A_1 = \alpha_{med} - \alpha_{\min}$

$A_2 = \alpha_{med} - \alpha_{\max}$

If $A_1 > 0$ AND $A_2 < 0$, go to Loop$B$ else increase the window size

If window size $\leq S_{\max}$ repeat Loop$A$ else output α_{xy}

Loop B:

$B_1 = \alpha_{xy} - \alpha_{\min}$

$B_2 = \alpha_{xy} - \alpha_{\max}$

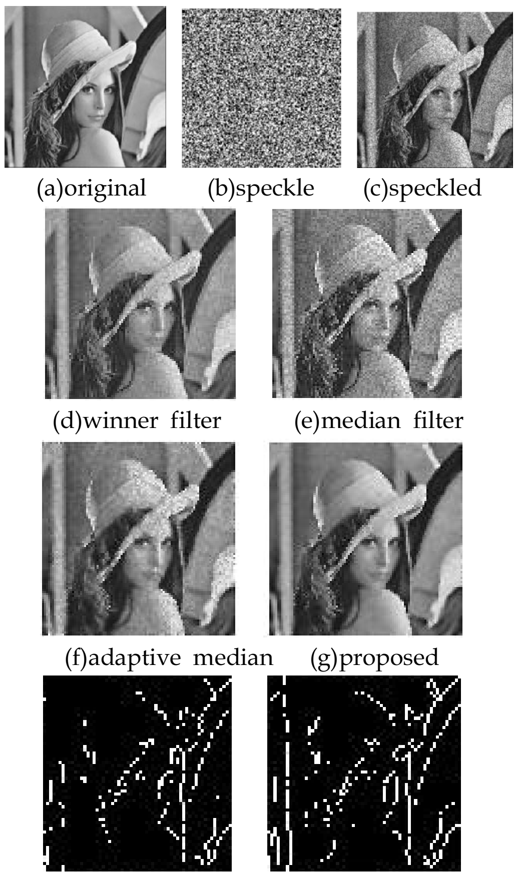
If $B_1 > 0$ AND $B_2 < 0$, output α_{xy} else output α_{med}

Ⅲ. EXPERIMENT AND RESULTS

The experimental sample images are ultrasound image and CCD image, image size is 256×256, and speckle noise variance is 0.05. The ultrasound images are a thyriod gland and an embryo. The proposed method performance shows Fig. 2 and Fig. 3, and Table 1 and Table 2 with PSNR and EPI on the several conventional methods in objectivity decision standard. EPI is that P_s is done after filtering intensity of light pixel in (i.j), P_v is done before intensity of light.

$$EPI = \frac{\sum |P_s(i,j) - P_s(i-1,j+1)|}{\sum |P_v(i,j) - P_v(i-1,j+1)|}$$

As shown in the Tables the method enhances the image to about 20% in comparison with Winer filter by Edge Preservation Index because the Winer filter is the best EPI of the conventional methods, and in the case of adaptive, is 40%. The edges are preserved than the conventional edge intuitively. PSNR is similar. However the processing time takes 1.5 times more.



(a)original (b)speckle (c)speckled

(d)winner filter (e)median filter

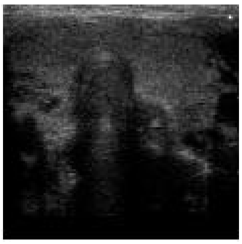
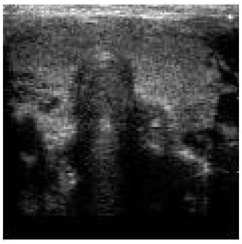
(f)adaptive median (g)proposed

(h)edge of (f) (i)edge of(g)

Fig 2. The results image of CCD sample

Table 1. CCD image PSNR and EPI

Image	Filter	PSNR	EPI
Fig. 2(d)	winer	26.065	0.282
Fig. 2(e)	median	20.035	0.058
Fig. 2(f)	adaptive median	23.204	0.197
Fig. 2(g)	morphological adaptive median	26.066	0.391

(a)thyroid image (b)result image


(c)embryo image (d)result image


(e)edge of(e) (f)edge of (d)

Fig. 3 The results of ultrasound image

Table 2. Ultrasound images PSNR and EPI

Image	PSNR	EPI
Fig. 3(b)	23.327	0.386
Fig. 3(d)	26.623	0.401

Ⅳ. CONCLUSION

Speckle noise reduction for ultrasound CT image using morphological adaptive median filtering based on edge preservation is presented. Speckle noise is multiplicative feature and causes ultrasound image to degrade widely from transducer. An input image is classified into edge region and homogeneous region in preprocessing. The speckle is reduced, and edges are preserved by the morphological adaptive median filtering on the 2D gray scale image. This method enhances the image to about 20% in comparison with Winer filter by Edge Preservation Index and PSNR. However the processing time takes about 1,5 times in comparison with the conventional methods. This algorithm has achieved good success in the applications to image restoration, noise suppressing, edge extraction and pattern recognition.

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