Edge Preserving Speckle Reduction of Ultrasound Image with Morphological Adaptive Median Filtering

Kwang Ryol Ryu and Eun Suk Jung, *Member, KIMICS*

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 to preserve edges. As the result, MAM of the proposed method enhances the image to about 10% in comparison with Winner filter by Edge Preservation Index and PSNR, and 10% to only adaptive median filtering.

Index Terms—Morphological adaptive median filtering, Speckle noise reduction, Edge preservation index

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

Kwang Ryol Ryu is with the Department of Electronic Engineering, Mokwon University, Daejeon, 302-729, Korea (Tel: +82-42-829-7650, Fax: +82-42-823-8506, Email: conan@mwu.ac.kr)

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, erosion, opening and closing operations in an image such as boundaries. These components will preserve 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 convolution 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. MORPHOLOGICAL ADAPTIVE MEDIAN FILTERING

A. 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

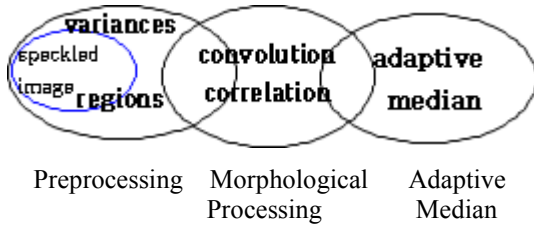gray scale image. That is the MAM (Morphological Adaptive Median).

Fig. 1 Algorithm structure

B. Noise and signal Variances

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

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

, where $S_{i,j}$ are image pixel included noise, $x_{i,j}$ and $n_{i,j}$ are the pixel of original 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)

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

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

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 $x_{i,j}$

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

C. Morphological Algorithm

The fundamental operations, dilation expands an image and erosion shrinks it. The opening generally smoothes the contour of an object, breaks narrow isthmuses, and eliminates thin protrusions. The 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

$$(f \oplus b)(s,t) = \max \left\{ f(s-t,t-u) + b(x,u) : \atop (s-x),(t-u) \in D_f; (x,u) \in D_b \right\} \qquad (5)$$

, where $f(x,u)$ is the input image, $b(x,u)$ 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

$$(f \ominus b)(s,t) = \min \left\{ f(s+t,t+u) - b(x,u) : \atop (s+x),(t+u) \in D_f; (x,u) \in D_b \right\} \qquad (6)$$

The erosion equation is similar to 2D correlation with the min operation replacing the sums of correlation and subtraction replacing the products of correlation. The opening operation and the closing operation are given by the following equations respectively.

$$\text{Opening:} \quad f \circ b = (f \ominus b) \oplus b,$$

$$\text{Closing:} \quad f \cdot b = (f \oplus b) \ominus b$$

D. 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: α_{min} = minimum gray level in ω_{xy}, α_{max} = maximum gray level value in ω_{xy}, α_{med} is median of gray levels in ω_{xy}, α_{xy} is gray level at coordinates (x,y), ω_{max} is maximum allowed size of ω_{xy}. The adaptive median filtering algorithm processes in two loops, denoted loop A to 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 puts 0.05 calculated. The ultrasound images are processed by a thyroid gland and an embryo. The performance of proposed method MAM shows Fig. 2 and Fig. 3, and Table 1 and Table 2 with PSNR and EPI in relating to 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.

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

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

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[(x(i,j) - s(i,j))^2]$$

As shown in the Tables 1 the method enhances the image to about 10% in comparison with Winner filter by Edge Preservation Index because the Winner filter is the best EPI of the conventional methods, and 10% to only morphological filtering in the Table 2. The edges are preserved than the conventional edge intuitively. The similar PSNR results from equation. However the processing time takes 1.5 times more.
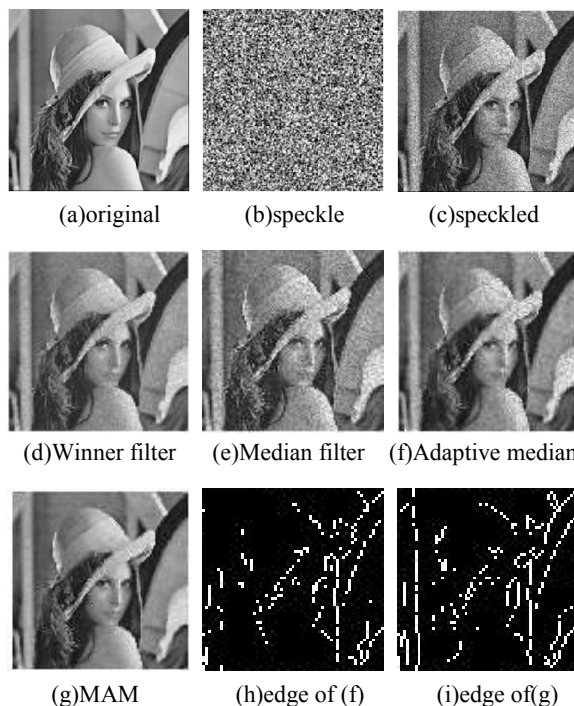

(a)original (b)speckle (c)speckled

(d)Winner filter (e)Median filter (f)Adaptive median

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

Fig. 2 Result images of CCD sample

(a)thyroid image (b) result of (a) (c)embryo image

(d)result of (c) (e)edge of(c) (f)edge of (d)
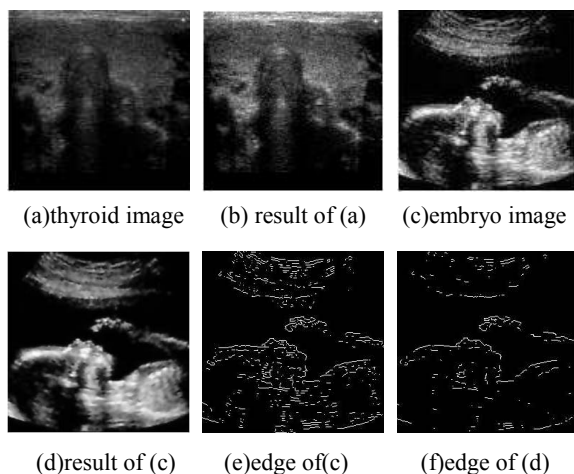
Fig. 3 results of ultrasound images

Table 1 CCD image PSNR and EPI

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

Table 2 Ultrasound images PSNR and EPI

Methods	Thyroid		Embryo	
	PSNR	EPI	PSNR	EPI
Median	20.78	0.38	21.38	0.29
Winner	23.02	0.41	25.97	0.34
Morphological op	20.33	0.43	23.21	0.37
Adaptive Median	21.91	0.20	25.00	0.38
MAM	23.32	0.38	26.62	0.40

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 operations which are erosion, dilation, opening and closing, and adaptive median filtering to reduce impulse noise on the 2D gray scale image. The edge preservation is evaluated by EPI index. This method enhances the image to about 10% in comparison with Winner filter by Edge Preservation Index and PSNR, and 10% to only adaptive median filtering. However the processing time takes about 1,5 times in comparison with the conventional methods. This algorithm has achieved good success in the applications image restoration, noise suppressing, edge extraction and pattern recognition to diagnose human organs with ease.

REFERENCES

[1] A. Macovski, Medical Imaging Systems, Prentice Hall. 1983.
[2] T. R. Nelson and T .T. Elvins, "Visualization of 3D Ultrasound Data", IEEE, Computer Graphics and Applications, vol. 13, pp. 50-57,Nov.1993
[3] A. Renster and A. B. Downey, "3D-ultrasound Imaging: A Review:, IEEE Engineering in Medicine and Biology Magazine, vol15, pp.41-51, Nov-Dec. 1996.
[4] Z. H. Cho, J, P. Jones and M. Singh, Foundation of Medical Image, John Wiley & Sons, 1994.
[5] B. Burckhardt. "Speckle in Ultrasound B-mode Scans", IEEE Trans. on Sonics and Ultrasonics. vol. 1, pp.1-6, Jan. 1978
[6] A. Thakur, R. S. Anand, "Speckle reduction in Ultrasound Medical Image using Adaptive Filter based on Second Order Statistics", Journal of Medical Engineering & Technology, vol.31, no.4,263-279, July/August 2007
[7] J.S. Lee. "A Simple Speckle Smoothing Algorithm for Synthetic Aperture Radar Images, IEEE Trans. on system, man, and, cybernetics, vol. 1, pp.85-89, Feb.1983
[8] T. Loupas, "An Adaptive Weighted Median Filter for Speckle Suppression in Median Ultrasonic Image", IEEE Trans. Circuits Syst. vol. 36, no. l, Jan, 1989.
[9] S. Gupa and et al, "A Versatile Technique for Visual Enhancement of Medical Ultrasound Images", Digital Signal Processing, ELSEVIER, pp. 542-560, 2007.

Kwang Ryol Ryu, PhD**.**
is currently a professor at the Dept. of Electronic Engineering at the Mokwon University, worked as a visiting Professor at the Dept. of Neurological Surgery at University of Pittsburgh Medical Center in USA, and is member of KIMICS and Signal processing society of IEEE in 1991. His areas of research include Digital Signal Processing, Imaging and Video processing, and Biomedical Electronics.

Eun Suk Jung
Received the B.E. and M.E. degrees at the Dept. of Electronic Engineering from Mokwon University, is currently Ph.D. course student at the Mokwon University in Korea, and member of KIMICS. Her areas of research include Biomedical Image Processing and Video Application.