SPECKLE NOISE REDUCTION FROM ULTRASOUND IMAGE USING ENHANCED SPECLE REDUCING ANISOTROPIC DIFFUSION

Sunil Kumar Yadav, Archit Kushwaha, Maneesh Sharma

ABSTRACT

Speckle reducing anisotropic diffusion (SRAD), a diffusion method tailored to ultrasonic medical imaging and radar imaging applications. In SRAD the instantaneous coefficient of variation is derived by taking account only 4 pixel of image. We proposed the new algorithm using SRAD that consider 8 neighbor pixel of image i.e. horizontal and diagonal pixel both. We also demonstrate the algorithm performance on some ultrasound image. The performance measures obtained by is considerable compare to existing noise reducing algorithm and better edge preservation, variance reduction, and edge localization.

Keywords: Speckle Noise, Ultrasound Medical imaging, Anisotropic Diffusion

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1. INTRODUCTION

In medical image processing, image de-noising has become a very essential for better information extraction from the image and mainly from so noised ones, such as ultrasound images [3]. Speckle noise is a form of local correlated noise that degrades the resolution and discriminates the fine details of ultrasound images. Speckle in ultrasound B-scans is seen as a granular structure which is caused by the constructive and destructive coherent interferences of back scattered echoes from the scatterers that are typically much smaller than the spatial resolution of medical ultrasound system[3]. This phenomenon is common to laser, sonar and synthetic aperture radar imagery (SAR)[6]. There are two main purposes for speckle reduction in medical ultrasound imaging[2].

(1) To improve the human interpretation of ultrasound images,

(2) Despeckling is the preprocessing step for many ultrasound image processing tasks such as segmentation and registration.

Speckle reduction is usually used as a critical preprocessing step for clinical diagnosis by ultrasound and ultrasound image processing.

2. BACKGROUND KNOWLEDGE

PDE for smoothing image on a continuous domain[1]:

$$\begin{Bmatrix} \dfrac{\partial I}{\partial t} = div[c(|\nabla I|).\nabla I] \\ I(t=0) = I_0 \end{Bmatrix}$$

Where ∇ is the gradient operator, div the divergence operator, | |denotes the magnitude, c(x) the diffusion coefficient, and the initial image. They suggested two diffusion coefficients:

$c(x) = \frac{1}{(1+\left(\frac{x}{k}\right)^2)}$ And

$c(x) = \exp(-\left(\frac{x}{k}\right)^2)$

Where k is an edge magnitude parameter.

In the anisotropic diffusion method, the gradient magnitude is used to detect an image edge or boundary as a *step* discontinuity in intensity. If $|\nabla I| \gg k$, then $c(|\nabla I|) \to 0$, and we have an all-pass filter; if $|\nabla I| \ll k$, then. $c(|\nabla I|) \to 1$, and we achieve isotropic diffusion (Gaussian filtering)[1].

A discrete form of Anisotropic Diffusion is given by:

$$I_s^{\,t+\nabla t} = I^t{}_s + \frac{\Delta t}{|\eta_s|} \sum_{p \in \eta_s} c\left(\nabla I^t{}_{s,p}\right).\nabla I^t{}_{s,p}$$

Where $I^t{}_s$ is the discretely sampled image, s denotes the pixel position in a discrete two-dimensional (2-D) grid, and Δt is the time step size, η_s represents the spatial neighborhood of pixel , $|\eta_s|$ is the number of pixels in the window (usually four, except at the image boundaries), and

$$\nabla I^t{}_{s,p} = I_p^t - I_s^t, \forall\, p \in \eta_s$$

2.2.Speckle Reducing Anisotropic Diffusion: By extending the PDE versions of

$$I_{i,j}^{t+\Delta t} = I_{i,j}^t + \frac{\Delta t}{|\eta_s|}\, div\left[c(C_{i,j}^t)\nabla I_{i,j}^t\right]$$

Where c(…) is a bounded nonnegative decreasing function. As with conventional anisotropic diffusion, c(…) is the diffusion coefficient[2].

To derive a PDE version of the classical speckle reducing filters, we must examine the coefficient of variation in conjunction with developing a diffusion coefficient c(…) that inhibits smoothing at the edges. Specifically, we need to derive a discretized version of the coefficient of variation that is applicable to PDE evolution. In a sense, this function can be called an "instantaneous coefficient of variation."

First, we write the local variance estimate of intensity in as:

$$\frac{1}{|\eta_s|} \sum_{p \in \eta_s} \left(I_p - \overline{I_{i,j}}\right)^2 = \overline{(I^2)_{i,j}} - \left(\overline{I_{i,j}}\right)^2$$

Where $\overline{(I^2)_{i,j}}$ is the average of intensity squared at position (i, j).

$C_{i,j}$ is usually called local coefficient of variation, we call the function the instantaneous coefficient of variation. It combines a normalized gradient magnitude operator and a normalized Laplacian operator to act like an edge detector for speckled imagery. High relative gradient magnitude and low relative Laplacian tend to indicate an edge.

$$C_{i,j}^2 = \frac{\frac{1}{2}\left|\nabla I_{i,j}\right|^2 - \frac{1}{16}\left(\nabla^2 I_{i,j}\right)^2}{\left[I_{i,j} + \frac{1}{4}\nabla^2 I_{i,j}\right]^2}$$

and coefficient of variation used for update the image recursively.

3. Enhanced Speckle Noise Reducing Anisotropic Diffusion:

Here we are going to define the two coefficient of variation. One regarding the horizontal and vertical direction where as other one regarding the diagonal direction.

$$C1_{i,j}^{2} = \frac{\frac{1}{2}\left|\nabla I1_{i,j}\right|^{2} - \frac{1}{64}\left(\nabla^{2} I1_{i,j}\right)^{2}}{\left[I_{i,j} + \frac{1}{8}\nabla^{2} I1_{i,j}\right]^{2}}$$

Where $C1_{i,j}^{2}$ counted considering only horizontal and vertical pixel of neighborhood[1].

And

$$\left|\nabla I1_{i,j}\right|^{2} = \frac{\left(\left|\nabla_L I_{i,j}\right|^{2} + \left|\nabla_R I_{i,j}\right|^{2}\right)}{2}$$

And

$$\nabla_L I_{i,j} = [I_{i,j} - I_{i-1,j}, I_{i,j} - I_{i,j-1}]$$

$$\nabla_R I_{i,j} = [I_{i+1,j} - I_{i,j}, I_{i,j+1} - I_{i,j}]$$

And laplacian of the image considering above condition:

$$\nabla^{2} I1_{i,j} = \frac{I_{i+1,j} + I_{i,j+1} + I_{i-1,j} + I_{i,j-1} - 4I_{i,j}}{h^{2}}$$

Now we consider the diagonal element of neighborhood pixel and define local coefficient of variation:

$$C2_{i,j}^{2} = \frac{\frac{1}{2}\left|\nabla I2_{i,j}\right|^{2} - \frac{1}{64}\left(\nabla^{2} I2_{i,j}\right)^{2}}{\left[I_{i,j} + \frac{1}{8}\nabla^{2} I2_{i,j}\right]^{2}}$$

Where

$$\left|\nabla I2_{i,j}\right|^{2} = \frac{\left(\left|\nabla_{D1} I_{i,j}\right|^{2} + \left|\nabla_{D2} I_{i,j}\right|^{2}\right)}{2}$$

And

$$\nabla_{D1} I_{i,j} = [I_{i,j} - I_{i-1,j-1}, I_{i,j} - I_{i-1,j+1}]/\sqrt{2}$$

$$\nabla_{D2} I_{i,j} = [I_{i+1,j-1} - I_{i,j}, I_{i+1,j+1} - I_{i,j}]/\sqrt{2}$$

let h=1

$$\nabla^{2} I2_{i,j} = \frac{I_{i+1,j+1} + I_{i-1,j+1} + I_{i-1,j-1} + I_{i+1,j-1} - 4I_{i,j}}{(\sqrt{2}h)^{2}}$$

We denote the special case of $C1_{i,j}^{2}$ and $C2_{i,j}^{2}$, one that is computed over η_s, by $q1_{i,j}$ and $q2_{i,j}$ for convenience and assume that the image intensity function has no zero point over its support. So $q1_{i,j}$ and $q2_{i,j}$, can be viewed as a discretization of

$$q1 = \sqrt{\frac{\frac{1}{2}\left(\frac{|\nabla I1|}{I}\right)^{2} - \frac{1}{64}\left(\frac{\nabla^{2} I1}{I}\right)^{2}}{\left[1 + \left(\frac{1}{8}\right)\left(\frac{\nabla^{2} I1}{I}\right)\right]^{2}}}$$

And

$$q2 = \sqrt{\frac{\frac{1}{2}\left(\frac{|\nabla I2|}{I}\right)^{2} - \frac{1}{64}\left(\frac{\nabla^{2} I2}{I}\right)^{2}}{\left[1 + \left(\frac{1}{8}\right)\left(\frac{\nabla^{2} I2}{I}\right)\right]^{2}}}$$

Based on previous discussion, we propose a new anisotropic diffusion method for smoothing speckled imagery. Now define the diffusion coefficient:

$$c1(q) = \frac{1}{1 + [q1^{2} - q_0^{2}]/[q_0^{2}(1 + q_0^{2})]}$$

or

$$c1(q) = \exp\{-[q1^{2} - q_0^{2}]/[q_0^{2}(1 + q_0^{2})]\}$$

And

$$c2(q) = \frac{1}{1 + [q2^{2} - q_0^{2}]/[q_0^{2}(1 + q_0^{2})]}$$

or

$$c2(q) = \exp\{-[q2^{2} - q_0^{2}]/[q_0^{2}(1 + q_0^{2})]\}$$

where

$$q_0 = \frac{\sqrt{var[z]}}{\bar{z}}$$

Where var[z] and $\bar{z}$ are the intensity variance and mean over a homogeneous an area , respectively[1].

now we calculate the divergence of c(.)∇I , needed for the SRAD PDE:

$$D1_{i,j} = \frac{1}{\square^{2}}\left[c1_{i+1,j}\left(I_{i+1,j} - I_{i,j}\right) + c_{i,j}\left(I_{i-1,j} - I_{i,j}\right) + c_{i,j+1}\left(I_{i,j+1} - I_{i,j}\right) + c_{i,j}\left(I_{i,j-1} - I_{i,j}\right)\right]$$

And

$$D2_{i,j} = \frac{1}{2h^2}\left[c1_{i+1,j+1}\left(I_{i+1,j+1} - I_{i,j}\right) + c_{i,j}\left(I_{i-1,j-1} - I_{i,j}\right) + c_{i-1,j+1}\left(I_{i-1,j+1} - I_{i,j}\right) + c_{i,j}\left(I_{i+1,j-1} - I_{i,j}\right)\right]$$

$$D_{i,j} = D1_{i,j} + D2_{i,j}$$

Finally, by approximating time derivative with forward differencing, the numerical approximation to the differential equation is given by:

$$J_{i,j} = I_{i,j} + \frac{\Delta t}{8} D_{i,j}$$

Where Δt is the time step.

4. Conclusion and Result:

We have presented here an enhanced Speckle Reducing Anisotropic diffusion algorithm, in which we are considering the all eight neighborhood of current pixel for filtering of ultrasound image. That provides a satisfactory result on the different ultrasound image.

Figure 1 and 2 shows the input and output image respectively regarding enhanced algorithm:

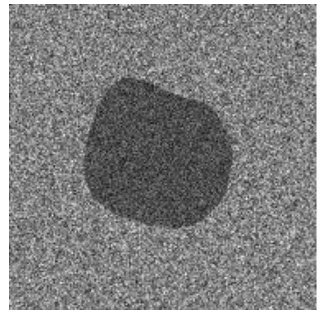

Figure: 1

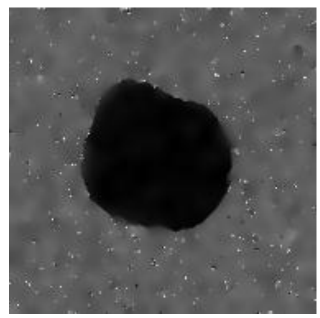

Figure: 2

Now we are showing some statistical data regarding different algorithm used in the filtering purpose in the following table:

TABLE(statistical data regarding different algorithm**)**

Parameter	Experiment 1(N=200)	Experiment 2(N=200)	Experiment 3(N=20)
Mean(Noisy image)	0.4099	0.3300	0.2807
Std Dev(Noisy image)	0.1287	0.2385	0.1681
Mean(Gaussian)	0.4099	0.3300	0.2807
Std Dev(Gaussian)	0.1148	0.2347	0.1643
Mean(SRAD)	0.3465	0.3306	0.2830
Std Dev(SRAD)	0.1166	0.2361	0.1557
Mean(ESRAD)	0.3464	0.3307	0.2829
Std Dev(ESRAD)	0.1165	0.2359	0.1547
PSNR(SRAD)	68.1247	73.1941	73.5909
PSNR(ESRAD)	68.2012	73.2810	74.5898
EKI(SRAD)	0.8012	0.7555	0.8222

EKI(ESRAD)	0.8011	0.7556	0.8221

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