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Denoising Ultrasound Medical Images with Selective Fusion in Wavelet Domain

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Abstract

Ultrasound medical imaging is undoubtedly an incontestable tool which provides the view of the internal organs of a body. The no ionizing radiation exposure property of the ultrasound medical images made it more fitting for fetus imaging. The only major snag ultrasound imaging encompasses is speckle noise that results from constructive and destructive interference thereby degrading the quality of the image. This paper submits a twofold technique to remove this multiplicative speckle noise and to bring a contrast between the object of the interest and the remaining image. First fold includes block based hard (BHT) and soft thresholding (BST) on pixels in wavelet domain where in which the original ultrasound image is divided into Non Overlapping blocks of sizes 8, 16, 32 and 64. The second fold includes restoration of the object boundaries and texture with adaptive wavelet fusion which are lost by the blurring effect caused as a result of the first fold. Fusion of wavelet coefficients of original US image and block thresholded US images assuaged to restore the degraded object. Fusion rule and wavelet decomposition level are made adaptive for each block using gradient histograms with normalized differential mean (NDF) to introduce highest level of contrast between the denoised pixels and the object pixels in the resultant image. Thus the proposed twofold methods are named as adaptive NDF block fusion with hard and soft thresholding (ANBF-HT and ANBF-ST). Visual quality through twofold processing has improved to an interesting level. Peak signal to noise ratio (PSNR), normalized cross correlation coefficient (NCC), edge strength (ES), image quality Index (IQI) and structural similarity index (SSIM), measure the quantitative quality of the twofold processing technique. Validation of the proposed method is done by comparing with anisotropic diffusion (AD), total variational filtering (TVF) and empirical mode decomposition (EMD) for enhancement of US images. The US images are provided by AMMA hospital radiology labs at Vijayawada, India.

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1. Introduction

Here Ultrasound imaging emerged as a boon to study the internal tissues of a human body especially for the pregnant women because of its several advantages over the Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Positron Emission Technology (PET). Unfortunately the presence of multiplicative Speckle noise which is difficult to model in real time depraved the visual quality of the ultrasound images. The extensive research done by the researchers at device level led to the introduction of the 3D and 4D [3] ultrasound imaging devices but that was not cost friendly to the common man. The image level research done using spatial domain and frequency domain techniques resulted with some other new cons such as inducing blur. This research paper proposes a novel approach to lessen the effect of the speckle [4-7] in the Ultrasound image. The proposed method calculates the wavelet coefficients from medical image using a multiresolution filter bank approach. The coefficients scaling of amplitude is soft and hard thresholding. Wavelet based object edge reconstruction [19] on the thresholded medical images by using fusion technique is proposed. The wavelet based fusion [20] acts as a value addition to thresholded images to restore the edges of objects in the ultrasound image. This twofold algorithm reduces speckle noise and restores edge quality for better and faster diagnostics by doctors. Verification of the proposed method by doctors at AMMA Hospital, Vijayawada, INDIA and NRI Medical college Hospital, Guntur, INDIA were initiated. The rest of the paper is organizes as follows. Section 2 gives twofold technique using wavelet transform. Section 3 discusses the results of the proposed algorithm on ultrasound medical image of fetus obtained from AMMA hospital Vijayawada. Section 4 compares the results from the proposed algorithm with the results from standard denoising algorithms on medical images. Section 5 concludes the proposed research based on experiments conducted in the previous sections.

2. Two Fold Processing

As the name suggests the proposed technique involves two main processes namely block thresholding of the ultra sound medical images and the fusion of the thresholded image with the original image. Block based thresholding of wavelet coefficients compensates the edge loss caused due to global thresholding by making the thresholding local to that particular block and preserving the contrast in the ultrasound images. Two classes of thresholding algorithms are used to filter wavelet coefficients. They are Hard Thresholding (HT) and Soft Thresholding (ST) [21]. After thresholding on detailed wavelet coefficients the inverse transformation using the low pass and high pass reconstruction filter results in a quality image though it has some blocky artifacts in it when the block size is very small comparable to the original image. The solution to the edge blurring and blocky artifacts can be reduced using the proposed fusion technique. Fusion process helps to restore the lost edges due to the blurring effect caused by thresholding and also improves the contrast. The fusion aims to combine wavelet coefficients of block denoised US image $U^{(d)}(x,y)$ with original ultrasound medical image $U(x,y)$. The coefficients of different blocks fuse together by selection of fusion rules and levels in wavelet for each block. Here adaptive block fusion ensures correct fusion rule at a particular level preserves object properties such as edge and contrast. Wavelet level select and fusion type are selected based on the properties of object strength present in the blocks. The object strength parameter is edge strength [8] of each denoised block. Edge strength is most widely used in image processing to measure the quality edge detection algorithms [8]. Here it measures the strength of edges in the original US image which contribute towards object characteristics. Two D gradient operator calculates the edge magnitude $\varepsilon(x,y)$ and edge orientation $\theta(x,y)$ for each pixel in the block. For the original ultrasound image $U(x,y)$, it is defined as

$$\varepsilon^b(x,y) = \sqrt{g_x^b(x,y)^2 + g_y^b(x,y)^2} \tag{1}$$

$$\theta^b(x,y) = \tan^{-1}\left(\frac{g_y^b(x,y)}{g_x^b(x,y)}\right) \tag{2}$$