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Comparative Analysis of Wavelet Transform for Medical Image Denoising

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ABSTRACT: Image denoising is one of the key research areas in the field of image processing and wavelet transform has been used in many denoising application. This can also be used as a pre-processing stage to improve the results of higher level applications. preservingthe main features of an image such as edges, textures, colors, contrast while removing the noise has been a tedious job over the years.The framework proposed in this paper is for denoising an image based on applying image denoising techniques. Here, the denoising technique is applied to the image in the moving frame instead of applying the technique to the image itself.We have applied wavelet transform for denoising some standard biomedical images embedded with various types of noises. In this paper, a comparative analysis of denoising results, obtained after implementing our technique on extensive set of biomedical images, is discussed.SNR of noisy and denoised images are compared. Further, our framework can be applied to noisy images whose noise model is unknown to the user. The proposed approach is more realistic and improves the overall performance by effectively handling the Gaussian and also other common noise models.

INTRODUCTION

De-noising is one of the crucial steps involved in image processing. Denoising belongs to the family of image enhancement methods which also includes blur reduction, resolution enhancement, artifacts suppression, and edge enhancement.[1] Basically, de-noising finds its major applications in medical image analysis, data mining, radio astronomy image analysis and so on.

Medical imaging plays an important role in clinical diagnosis producing high quality 2-D and 3-D images of the internal organs of the body, is also affected by noise [2]. Several de-noising techniques have been proposed in recent years in literature. The challenge is to reduce the amount of noise, i.e. regularize the medical image, while preserving the details, the edges and in general the small structures that could be criticalin proper diagnosis [3]. Three main medical image denoising filter families can be identified: methods defined in the spatial domain, transformed domain and exploiting the statistical properties of the signals [4].

De-noising can be done in various domains like Spatial Domain, Frequency Domain and Wavelet Domain. Filtering is a technique in medical image processing which is used for various tasks such as reducing the noise, interpolation, and resampling [5]. The selection of filter depends upon which type the noise belong to and extent of noise present in that image. Average filter is found to show better performance in removing Speckle noise while Gaussian filter removes Poisson noise efficiently. The adaptive median filter is found to perform better in removing Salt

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&Pepper, Uniform, Rayleigh and Erlang noise[6].

The paper is organized as follows. A study on the previous works on image processing is done in section II. Section III briefly explains the wavelet domain denoising. Proposed approach is explained in detail in Section IV including the need for the decomposition and reconstruction of wavelet. Results are briefly discussed in section V. The discussion and future scope of the work is highlighted in section VI.

Literature Survey

Various approaches for denoising an image areproposed by researchers and a huge amount of literature is available in the field of medical image analysisand the survey of such literatures is as follows.

In [1-2], image is first decomposed using filter into eight sub-bands using 3D DWT and bilateral filter technique. Bilateral filtering is done for the approximation coefficients obtained from the DWT and the detail coefficients are then subjected to wavelet thresholding.IDWT is applied on the resultant coefficients to reconstruct the image before applying a bilateral filter.

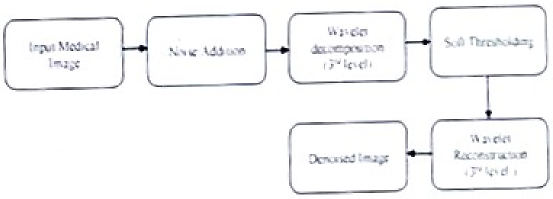

Figure 1. Framework for Image denoising

[3] reviews the important deep learning concepts pertinent to medical image analysis and abridgesmany contributions to this field. Denoising is illustrated by adding Gaussian noise as well as Salt and Pepper noise to MRI image. The suggested Median filter, Adaptive Median filter and Adaptive Wiener filter is applied on the noisy image. The noise density is added regularly to MRI image and the performance of filters is compared.In most of the filtering approaches based on Non-Local Means, a fixed filtering parameter is used neglecting the non-stationary noise nature. In the PC-NLM scheme, the neighbouring patches are decomposed first into the principal components by applying the principal component analysis (PCA)on them. NLM filtering is then used to regularize everyprincipal component of the target patch. These regularized components arethenconverted to get the target patch in image domain [7]. In the non-local means scheme, the filtering parameter is assessed from local noise level of the neighboring patches and the signal-to-noise ratio (SNR) of the corresponding principal component. Thus a "weaker" NLM filtering on PCs with higher SNR and a "stronger" filtering on PCs with lower SNR is obtained. The PC-NLM procedure is performed multiple times for removing the noise and artifacts effectively.To reduce the calculations by determining whether a particular patch is to be processed or not in the next round of filtering, an adaptive iteration approach is initiated.

Wavelet domain denoising

Significant investigations have been done in the field of medical imaging, using the wavelet transform as a tool, for improving medical images from noisy data. It is an efficient technique for the processing of a non-stationary signal. Wavelet transform can be used for decomposing a signal in the time frequency scale plane. In wavelet denoising, irrespective of the frequency content of the signal, the noise present in the signal is removed maintaining the signal characteristics. The discrete wavelet transform (DWT) decomposes the signal into mutually orthogonal set of waveletand provides a non-redundant and unique representation of the signal. Properties such as multiresolution, sparcity, edge detection and edge clustering make wavelet transform more powerful.

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In DWT, a filter pair called analysis filter consisting of a low pass filter and a high pass filter are chosen, such that they exactly halve the frequency range between themselves. First, the low pass filter is applied for each row of data to get the low frequency components of the row. As the low pass filter is a half band filter, the output data contains frequencies only in the first half of the original frequency range. They are subsampled by two, so that the output data will contain only half the original number of samples. After this, the high pass filter is applied for the same row of data, and the high pass components are separated, and placed by the side of the low pass components. This procedure is done for all rows.

The two-dimensional array of coefficients obtained after filtering each column of the intermediate data contains four bands of data, named as LL (low-low), HL (high-low), LH (low-high) and HH (high-high). The LL band can be decomposed once again in the same manner, thereby producing even more sub bands. This can be repeated to get a pyramidal decomposition.

Proposed Approach

The proposed framework has been divided into four main stages: noise addition, wavelet decomposition, soft thresholding and wavelet decomposition.

A. Noise Addition

Here, additive noise with a Gaussian distribution is considered as shown in equation (1). If we add Gaussian noise values of σ, we obtain the image as shown in figure 2.

$$g(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{z-\mu}{\sigma}\right)^2} \qquad (1)$$

Figure 2. Medical image with different levels of noise

B. Wavelet Decomposition:

Wavelet transforms have become an efficient tool in image denoising.[8] DWT has high decorrelation and energy compaction efficiency.[9]The information which is not significant is removed from the data by wavelet decomposition. This process is not reversible[10]. An image that is decomposed by wavelet transform can be reconstructed with desired resolution. The most important feature of wavelet transform is that it allows multiresolution decomposition. The decomposition of an image has been shown in figure 3. It consists of four images in result i.e. approximation coefficients and three details coefficients.

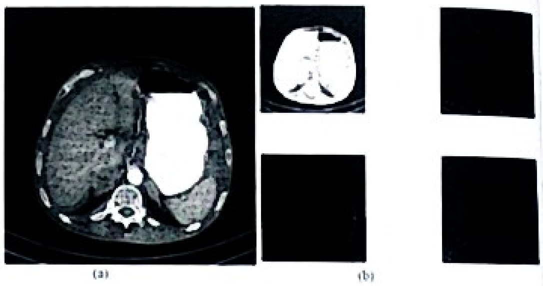

Figure 3. Biomedical image and its wavelet decomposition

C. Soft Thresholding

Wavelet thresholding is a technique which removes noise by killing coefficients that are insignificant relative to some threshold. Soft thresholding is a method which shrinks coefficients above the threshold in absolute value, where as hard thresholding is a 'keep or kill' method. Soft thresholding of $\boldsymbol{x}$: $\boldsymbol{Y} = \boldsymbol{sign}(\boldsymbol{X}).(|\boldsymbol{X}| - \boldsymbol{T})_+$

Where,

$$(\boldsymbol{x})_+ = \begin{cases} \boldsymbol{x} & \boldsymbol{if\ x \geq 0} \\ \boldsymbol{0} & \boldsymbol{otherwise} \end{cases}$$

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Wavelet shrinkage method has been used in soft thresholding. In this proposed approach, after the third level of wavelet decomposition all the detail coefficients have been passed to the soft thresholding stage.

D. Wavelet Reconstruction

In wavelet reconstruction, the approximation and details componentsare assembled back to get the original signal without loss of information. This process iscalledsynthesis. The reconstruction is done using Inverse Discrete Wavelet Transform (IDWT) from the various wavelet coefficients for each decomposition level. The detail and approximation coefficients at each stage are up-sampled by two.The coefficients are allowed to pass through high pass and low pass filters and later they are added.

Wavelet analysis involves filtering and downsampling, where the wavelet reconstruction process consists of up-sampling and filtering i.e., after passing through soft thresholding stage, all the approximation and details components are synthesized using wavelets to reconstruct the image which is noise free.

Results and Discussions

Various medical images are used in this approach and employed it to the multilevel image decomposition.

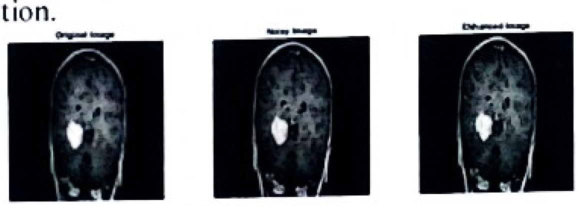

Figure. 4(a)

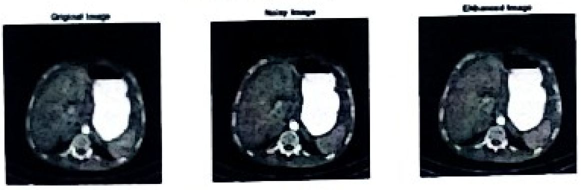

Figure. 4(b)

Figure. 4(c)

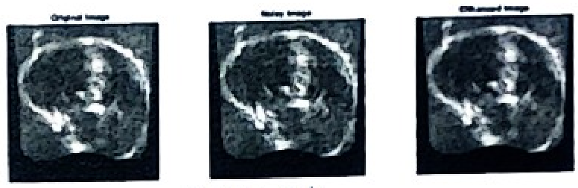

Figure. 4(d)

Figure. 4 Results of various biomedical images with the proposed approaches

A. Experimental Datasets

We have taken different images from the various database that comprises images of brain, lungs, mammograms etc. Figure 4(a) is a Magnetic Resonance Imaging (MRI) of the Lung Database Consortium image collection (LIDC-IDRI), which consists of diagnostic and lung cancer screening thoracic CT scans with marked-up annotated lesions shown in figure 4(b). 4(c), 4(d), show the mammogram images of breast and positron emission tomography (PET) scan respectively.

B. Results

Figure 4 shows the results on four different types of images with the proposed approach. First column shows the original image, second column shows the noisy image and third shows the denoised image using proposed algorithm. Results show that the images are appropriate after denoising applied.

Testing was carried out on different medical images and simulation is performed using MatLab R2015a software.

Table 1 shows the value of SNR before and after applying denoising technique and it shows that

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the value of SNR is increasing after applying our denoising approach.

Table 1 SNR performance analysis of proposed algorithm.

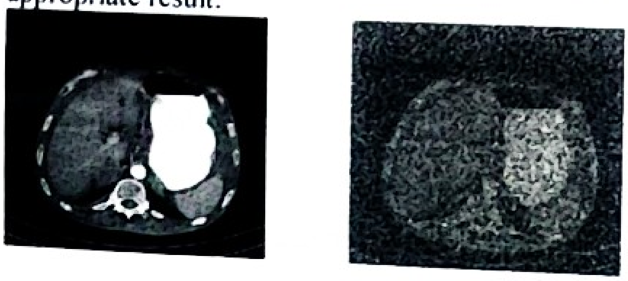
Images	Before de-noising	Afterdenoising
MRI	33.6460	40.2886
Lung CT scan image	23.0984	30.7630
Mammogram image	23.7864	29.5569
PET scan	23.6839	29.0771

Various types of mother wavelet are used to check the performance of proposed approach. The SNR value of the denoised image using different mother wavelets is shown in Table 2.

Sr.No	Mother Wavelet	SNR
1	Daubechies 2	40.2886
2	Daubechies 4	27.5316
3	Daubechies 10	17.984
4	Symlets 2	19.347
5	Fejer-Korovkin filters 4	19.3899
6	Biorthogonal 1.1	27.5127

C. Comparison of DCT and DWT

Discrete cosine transform and discrete wavelet transform have been compared here. The result has been shown in figure 5. The image and its result after cosine transform have been shown in figure 5. Same approach has been evaluated using DCT and results show that DCT doesn't give appropriate result.



(a) (b)

Figure 5. biomedical image with noise and (b) its result after denoising

CONCLUSION

In the proposed work, three level DWT decomposition and soft threshold approach is used. Wavelet thresholding is executed on the sub bands which are obtained from 3 level wavelet decomposition. Various database which include images of brain,lungs and mammogram has been taken to check the performance of the system and SNR of the denoised image is compared with the noisy image to check therobustness of the proposed approach. From the analysis, it is found that the SNR value of the denoised image obtained using 3 level wavelet decomposition method is satisfactorily high. Further work can be done using curvelet transform.

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