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MRI and CT Image Denoising using Gaussian Filter, Wavelet Transform and Curvelet Transform

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Abstract:
The medical images are facing a problem of high level components of noises. There are different techniques for producing medical images such as Magnetic Resonance Imaging (MRI), X-ray, Computed Tomography and Ultrasound, when this process occur noise is added that decreases the image quality and image analysis. Denoising techniques are used to remove the noise or distortion from images while preserving the original quality of the image. In this paper, we give a review on Gaussian filter, Wavelet Transform and Curvelet Transform on noisy image. Noises in form of Gaussian noise and random noise are present in the image.

Keywords: Gaussian filter, Discrete Wavelet Transform, Curvelet Transform, image processing, PSNR, RMSE, QI, SSIM.

I. INTRODUCTION

Image denoising is a procedure in digital image processing aiming at the removal of noise, which may corrupt an image during its acquisition or transmission, while retaining its quality. Medical images obtained from MRI, CT and X-ray is the most common tool for diagnosis in medical field. These images are often affected by random noise and Gaussian noise. The presence of noise not only produces undesirable visual quality but also lowers the visibility of low contrast objects. Noise removal is essential in medical imaging applications in order to enhance and recover fine details that may be hidden in the data. Medical images are typically corrupted with noise, which hinder the medical diagnosis based on these images. There has been substantial interest in the problem of denoising of images in general tools from traditional image processing field have been applied to denoised MR images [1]. However, the process of noise suppression must not appreciably degrade the useful features in an image. In particular, edges are important features for medical images and thus the denoising must be balanced with edge preservation. Wavelets are popular for such image denoising and enhancement applications because they have good localization properties both in space and frequency. Wavelets do not isolate the smoothness along the edges, and thus more suitable for reconstruction of sharp point singularities than lines or edges. These shortcomings are addressed by Curvelet Transform.

II. LITERATURE SURVEY:

Sezal Khera and Sheenam Malhotra [2] represent survey on medical image de noising using various filters and Wavelet Transform. This paper gives the review of various de noising techniques such as different Filters and Wavelet transform. Manyu and sheng zheng [3] present a new image denoising method based on Gaussian filter. This paper proposes a new denoising algorithm based on Gaussian filter and NL-means filter, but it is quite different from them. In general, the experimental result shows this method is superior to Gaussian filter and NL-means filter, it neither like Gaussian filter which is easy to fuzzy edge, nor as the NL means filter which can't eliminate noise completely in order to keep good structure. Arin h. Hamad, hozheen o. Muhamad and sardar p. Yaba[4] presented de-noising of medical images by using some filters. In this different types of filters were used to remove the noises such as average filter, Gaussian filter, log filter, median filter, and wiener filter. This paper showed that the Gaussian filter is a suitable filter to remove the noise in the medical images. The simple wavelet based noise reduction was proposed by weaver [5] et al. The main drawback of this filtering method was that any small structures that are similar in size to the noise are eliminated. Anja Borsdorf, Rainer Raupach, Thomas Flohr, and Joachim Hornegger [6] proposed Wavelet Based Noise Reduction in CT-Images Using Correlation Analysis. In CT two spatially identical images can be generated by reconstructions from disjoint subsets of projections. For standard CT-scanners the two images can be generated by splitting up the set of projections into even and odd numbered projections. The resulting images show the same information but differ with respect to image noise. The analysis of correlations between the wavelet representations of the input images allows separating information from noise down to a certain signal-to-noise level. V Naga Prudhvi Raj [7] presented denoising of medical images using dual tree complex wavelet transform. It uses dual tree complex wavelet transform to decompose the image and shrinkage operation to eliminate the noise from the noisy image. In the shrinkage step they used semi-soft and stein thresholding operators along with traditional hard and soft thresholding operators and verified the suitability of dual tree complex wavelet transform for the denoising of medical images. The results proved that the denoised image using DTCWT (Dual Tree Complex Wavelet Transform) have a better balance between smoothness and accuracy than the DWT and less redundant than UDWT (Undecimated Wavelet Transform).

J.mohan,v. Krishnaveni, yanhui guo[8] gives a survey on the magnetic resonance image denoising methods. This paper introduced about magnetic resonance imaging and the characteristics of noise in MRI, the popular approaches are classified into different groups and an overview of various methods is provided. The denoising method's advantages and limitations are also discussed. Rajeshwari S., Sharmila T. Sree [9] presented a technique to improve the image quality by denoising and resolution enhancement. This paper concentrates the average, median and wiener filtering for image de noising and an interpolation based Discrete Wavelet Transform (DWT) technique for resolution enhancement. Tanay Mondal, Dr. Mausumi Maitra[10] presented denoising and compression of medical image in Wavelet 2D. Here image is first loaded in biorthogonal wavelet and level 3 is used. Then the level of soft threshold is selected for reducing the noise in the image. Yogesh S. Bahendwar, G.R.Sinha[11] proposed an efficient algorithm for denoising of medical images using Discrete Wavelet Transforms. In this paper the Biorthogonal wavelet (bior1.3) gave the best results compared to other wavelets for Medical images corrupted by random noise. Indulekha N R, M Sasikumar[12] derived Medical image denoising using three dimensional Discrete Wavelet Transform And Bilateral Filter. In this paper, image is first decomposed into eight subbands using 3D DWT and bilateral filter and Thresholding methods are incorporated. The approximation coefficient obtained from DWT is filtered using Bilteral filter and the detail coefficients are subjected to Wavelet Thresholding. It uses three dimensional discrete wavelet transform for denoising of 3D medical images Taruna grover [13] presented denoising of medical images using wavelet transform. In this paper, it has been observed that sym4 wavelet is most efficient among all three wavelets for removing the Gaussian noise with different variance in the medical images. In 2002 jean-luc stark et al [14] proposed the Curvelet Transform for image de-noising technique.

This paper shows that Curvelet Transform is better than Wavelet Transform and easy to understand. But its implementation in discrete domain is difficult. Sumit Kumar[15] defined Curvelet transform based on the combination of windowshrink and bayesshrink using modified window neighborhood processing. It also provides a better removal of noise from images without losing or affecting the useful information. But the author consider only Gaussian noise for removing purpose.

III. GAUSSIAN FILTER:

Gaussian filters are a class of linear smoothing filters with the weights chosen according to the shape of a Gaussian function [3]. The Gaussian smoothing filter is a very good filter for removing noise drawn from a normal distribution. The zero-mean Gaussian function in one dimension is

$$G(x)=e^{-\frac{x^2}{2\sigma^2}} \qquad (1)$$

Where the Gaussian spread parameter σ determines the width of the Gaussian. For image processing, the two dimensional zero-mean discrete Gaussian function,

$$g[i,j] = e^{-\frac{(i^2+j^2)}{2\sigma^2}} \qquad (2)$$

It is used as a smoothing filter [4].

IV. DISCRETE WAVELET TRANSFORM:

Wavelet Transform provides a framework in which a signal is decomposed, with each level corresponding to a coarser resolution or lower frequency band, and higher frequency bands. There are two main groups of transforms, continuous and discrete. Of particular interest is the dwt, which applies a two-channel filter bank (with down sampling) iteratively to the low-pass band (initially the original signal). The wavelet representation then consists of the low-pass band at the lowest resolution and the high-pass bands obtained at each step. This transform is invertible and non-redundant [16]. In a 2-D DWT, a 1-D DWT is first performed on the rows and then columns of the data by separately filtering and down sampling. This results in one set of approximation coefficients and three sets of detail coefficients, which represent the horizontal, vertical and dialog directions of the image i, respectively.

V. DISCRETE CURVELET TRANSFORM (DCT):

The basic process realization of the Curvelet Transform has the following sub-steps as described below [15].

A. Sub Band Decomposition:

The sub band decomposition is the very first step of Curvelet Transform which is carried out by utilizing wavelet transform. In sub-band decomposition we decompose the signal according to the varying levels of frequency where lower frequency levels depicts the lesser rate of change of pixel intensity values while higher one shows the high rate of change of intensity values. The main aim is to decompose the signal according to the varying frequency from lowest frequency to highest one provided the image size remaining the same as the original image. The decomposition is done defining a bank of filters P_0(δs, s>=0).

$$f(P_0 f, \Delta_1 f, \Delta_2 f\ldots\ldots\ldots) \qquad (3)$$

B. Smooth Partitioning:

The edge and curved surface properties are present typically in natural images, in order to analyze such properties the signal is divided into various sub-blocks so as to approximate an edge or curve nearly to a straight line so that the further process of Ridgelet analysis can be carried out on partitioned sub-bands easily. Each sub-band is windowed into squares of an appropriate scale as below:

$$\Delta_s f(w_Q \Delta_s f)_{Q\in Q_s} \qquad (4)$$

Where Qs denotes the collection of all dyadic squares of scale s. w_Q represents the collection of various smooth windows.

$$Q = \left[\frac{k_1}{2^s}, \frac{(k_1+1)}{2^s}\right) \times \left[\frac{k_2}{2^s}, \frac{(k_2+1)}{2^s}\right) \qquad (5)$$

Here Q denotes the collection of all such dyadic squares.

C. Renormalization:

Renormalization is carried out to transform discrete pixel coordinate values (i1, i2) into continuous pixel coordinate values (x1, x2).

$g_Q=(T_Q)^{-1}(w_Q\Delta_s f), \quad Q \in Q_s$ (6)

C. Ridgelet Analysis:

During Ridgelet analysis each square is analyzed via orthonormal Ridgelet system. Here the two dyadic subbands $[[2^{2s}.2^{2s+1}]$ and $[2^{2s+1}.2^{2s+2}]$ are merged and then analyzed with ridgelet transform.

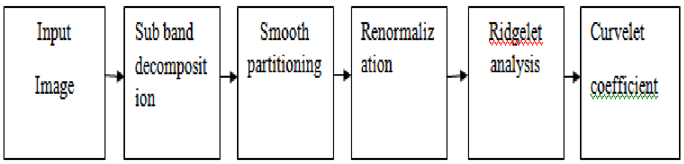


Figure.3. block diagram of Curvelet Transform.

VI. THRESHOLDING TECHNIQUES

Thresholding provides the basic tool and technique to remove unwanted information or we can say noise from the signal. Broadly we can classify the threshold into two categories namely hard thresholding and soft thresholding [17]. Hard thresholding as its name signifies has the ability to flush out all the pixel values going below the certain pre calculated threshold value its application can be seen where there is a lot of is present, whereas soft thresholding is used for lower magnitude noise in which we take the mode of the difference of threshold and pixel intensity at the particular point. This technique is used where there is chance losing information content of given image signal. In this paper we use soft thresholding technique.

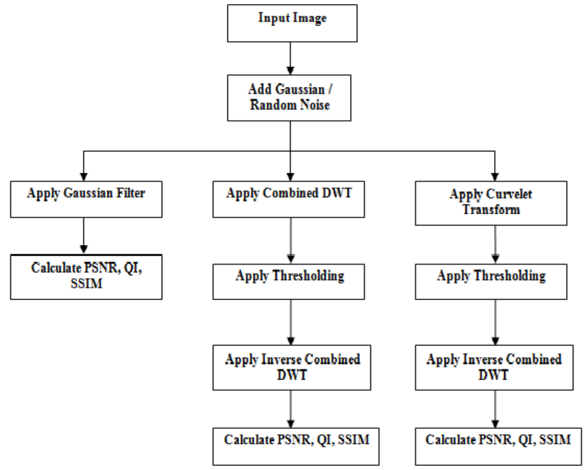
VII. METHODOLOGY

In this paper, we perform image denoising using Gaussian filter and Discrete Wavelet Transform and Curvelet Transform. Gaussian filtering mainly results in blurring of an image. So, Wavelet Transform is used which removes the noise without affecting signal characteristic. Wavelet Transform gives only approximate, horizontal, vertical and diagonal coefficient. Curvelet Transform gives more directional coefficient and better edges, curve features than wavelet transform

A. Algorithm

1. Take the images from user.
2. Check for the size.
3. If size is not same, resize the input images.
4. Convert image to gray scale image.
5. Apply noise (Gaussian noise or random noise) on the image.
6. Perform image denoising using Gaussian filter, Discrete Wavelet Transform and Curvelet Transform.
7. Evaluate the different parameters.
8. Display the input and output images.
9. Compare the results of Gaussian filter, discrete Wavelet Transform and Curvelet Transform.

D. Flow chart for the proposed work:



VIII. PERFORMANCE EVALUATION PARAMETERS

The most common full-reference quality metrics are MSE and PSNR. The definitions of these metrics are shown in the following subsections.

A. Mean Square Error (MSE)

MSE is the most widely used image quality assessment based on error sensitivity. It is computed by taking the average of squared intensity differences in every pixel of a reference image and a distorted image:

$$MSE=\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(x_{ij}-y_{ij})^2 \quad (7)$$

Where x_{ij} and y_{ij} are image gray values of reference image x and distorted image y, respectively. M and N are the width and the height of the images.

B. Peak Signal-To-Noise Ratio (PSNR)

The PSNR is most commonly used as a quality measurement for lossy compressed images. The PSNR is the ratio of the maximal power of original image and the noise power of distorted image. It is represented in the logarithmic domain because the powers of signals are usually in a wide dynamic range. Its formula is given by

$$PSNR=10log_{10}\frac{MAX^2}{MSE} \quad (8)$$

C. Quality Index (QI)

Quality index is the new parameter for comparison of quality of the image. Let y= $\{y_i|i=1,2\ldots\ldots N\}$ and z= $\{z_i\,|i=1,2,\ldots\ldots N\}$ be the original image and denoised image respectively. So the propose quality index is defined as,

$$Q=\frac{4\sigma_{yz}\dot{y}\dot{z}}{(\sigma_y^2+\sigma_z^2)[(\dot{y}^2)+(\dot{z}^2)]} \quad (9)$$

D. Structural Similarity Index Measure (SSIM):

The SSIM index is calculated on various windows of an image [16]. The measure between two windows x and y of common size *n*×*n* is:

$$SSIM(x,y)=\frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)} \quad (10)$$

IX. CONCLUSION

In this research paper we have reviewed the various methodologies for image denoising. Some research papers were discussed. All focusing on different aspects & techniques of image denoising. The medical images contain Gaussian noise and random noise. In this paper, Gaussian filter, discrete Wavelet Transform and Curvelet Transform based methods for medical image denoising was performed. The Gaussian filter gives better results only when it knows the noise value and for some particular value, it performs denoising otherwise not. Gaussian filtering mainly results in blurring of an image. Discrete Wavelet Transform performs denoising for any value of noise. From the literature survey, Curvelet Transform performs well for image denoising better than Gaussian filter and wavelet transform. In future work, we can denoise a medical image using different wavelets and removes poisons noise, papper noise and rician noise. Also we can use combination of Wavelet Transform and Curvelet Transform for better results.

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