Efficient Image Enhancement Techniques Applied on Medical Imaging-A State- of- The Art Survey

Munipraveena Rela, S. Nagaraja Rao, P. Ramana Reddy

ABSTRACT--- Medical image Enhancement is very crucial part to improve quality of medical images and to detect the diseases in the image. In this paper, a few image enhancement techniques used in literature are discussed. We also discussed different image quality parameters used to measure the quality of images. We also compared all the methods discussed in literature.

Index Terms— Computed tomography images, denoising, image enhancement, and Image fusion.

I. INTRODUCTION

Now a days, Medical images are very much essential to obtain information about internal organs. Usually Computed tomography, MRI and PET images are used to analyze internal organs. Most of the medical images are degraded with noise and other artifacts. Medical image enhancement is very important to enhance low contrast images for diagnosis purpose. In this paper, Section 2 gives a literature review. Section 3 describes CT image denoising methods. Section 4 includes the parameters used to measure the image denoising performance.

II. RELATED WORK

[1] Zohair Al-Ameen, developed a method of enhancement in spatial domain. This technique is applied directly on entire image instead of processing each and every pixel of the image. The following procedure is used to enhance the image: (i) obtain the size of processed image, (ii) calculate the enhancement variable (K) calculated using the following equaion:

$$K = \frac{\sum_{i=1}^{i}\sum_{j=1}^{j} x(i,j)}{m \times n}$$

Where x is the degraded image of size m X n. Finally, the image is enhanced using value k as shown in the following equation:

$$EI = \frac{[x - \min(x)] \times \mathrm{e}^{\mathrm{K}}}{[\max(x) - \min(x)]}$$

In [2] Fathi KALLEL, a technique for low contrast CT image enhancement is proposed. The algorithm is as follows: DWT is applied to the image, then SVD of LL sub band is obtained, then an adequate correction factor is used to generate an enhanced LL component, then inverse SVD is applied, then LL sub-band image is categorized into two classes as low contrast and moderate contrast classes, then adaptive dynamic gamma correction function and finally inverse DWT is applied

[3] P. Sreeja, used following procedure: The image is filtered using range filter with 7X1 and 1X7 kernel and added filtered images together to get edge of the image. The Gaussian low pass filter and gradient magnitude is used to smoothen the image and to enhance the edges of image respectively. The fusion rule are applied to the input image and to the Gaussian filtered image. To obtain better texture enhancement, fused the original image and Gaussian image. The better edge enhancement is obtained by fusing gradient magnitude image with the original image.

In [4] Manoj Diwakar, recommended a denoising technique which can be used for two identical images with uncorrelated noise. In this denoising method, noise in the first input image is eliminated by applying non-local means (NLM) filter and a wavelet packet thresholding technique is used to eliminate noise in the second image. The output due to NLM filter gives very good noise suppression but the small details of the input image would not be recovered properly. To recover small details of input image, the wavelet packet thresholding technique using correlation is used. This method is outstanding for noise suppression and structure preservation.

In [5] Khakon D, A Denoising scheme using Haar wavelet transform for brain images is proposed. To enhance the brain images, combine two images of brain obtained using two different modalities is image fusion. Modified Haar wavelet transform using lifting and in-place calculation has shown efficient performance relating to denoising parameters.

In [6] Huafeng Li, designed a low-rank sparse component de- composition and dictionary learning method for fusion, denoising, and improving quality of medical images. Specifically, in the dictionary learning model, low-rank and sparse regularization are used to increase the capability of the learned dictionaries. Additionally, in the image decomposition model, the sparse component is designed using a weighted nuclear norm and sparse constraint to eliminate noise and reserve textural details. Lastly, the fused image is obtained by merging the low-rank and sparse components of the source images.

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In [7] Jinlan Guan, a medical image enhancement method by using fractional differential and directional derivative is presented. This method is based on the image edge, clarity, texture information and structural features of different pixels, as well as the directional derivative of each pixel in constructing the masks. This method improves both high frequency content and low frequency content of the image. Finally, this method improves the texture information of the image.

[8] Ebenezer Daniel, proposed a dynamic unsharp masking technique using Optimum wavelet based masking (OWBM)

[9] Xuehang Zheng, proposed a PWLS (penalized weighted least squares) using Union of Learned TRAnsforms (PWLS-ULTRA) reconstruction method. The square transforms union is designed from several patches of image taken from CT images. The PWLS-based cost function is improved by interchanging between a clustering step, a sparse coding, and CT image reconstruction step. A Lagrangian technique with ordered-subsets is used to reconstruct the CT image reconstruction so that it decreases the forward and back projections. For both low-dose level and normal-dose level, this technique considerably increases reconstructed image quality when it is compared to PWLS-EP (PWLS with a non-adaptive edge preserving regularizer) reconstruction. This method gives better results in image reconstructions compared to a single learned square transform. Image quality and uniformity image resolution can be improved when PWLS-ULTRA designed using weights based on patches.

III. CT IMAGE DENOISING METHODS

There are various methods present for image denoising [11,12].Generally, image denoising can be done in : (i) transform domain methods and (ii) spatial domain methods

A. *Spatial domain filtering*

Spatial filters reduce noise in original noisy image by applying spatial filtering mask directly on all pixels of original input. Spatial filters are: (1) linear spatial filters and (2). non-linear spatial filters.

a. *Linear and non-linear filters*

Linear filters are used to decrease the noise in spatial domain but the details over the images cannot be obtain properly. The Gaussian noise can be reduced by mean filtering but this filter blurs the image if it contains high frequency noise component. Non-linear filters like median filter is used to remove impulse noise. A low pass filter in spatial domain operated on neighborhood of pixels by considering that the noise occupied at the high frequency. Generally, linear filters also introduces blur in the image.

The low contrast CT image quality is not good when compared with high dose CT images. Low contrast images in the CT occur when the photon detectors receive less information. Low contrast images are also used in diagnostic when the quality of these low contrast CT images will be enhanced by using image processing algorithms [10].

b. *Non-local means (NLM)and Bilateral filters*

Non local mean filter replace each and every pixel in input using a weighted average from a specified region of image. Bilateral filter is a non-linear, smoothing, noise-reducing, and edge enhancement filter. Both Non-local means filters and bilateral give good output in relations to noise decrease and enhancing the details of image.

B. *Transform domain filtering*

Wavelets are functions used to decompose image into dissimilar frequency constituents. Wavelet transform is a technique for image processing applications due to its localized in frequency, sub banding, multi-resolution analysis, and time domain.

a. *Wavelet* Transformed *based denoising*

In DWT, two parameters should be defined. First, a wavelet function is used for decomposition. The decomposition can be done by following wavelet decomposition filter: haar, meyr, dmey, db, sym, coif, bior, rbio, gaus, and etc. Next, decomposition level is chosen for thresholding all sub bands. The procedure for noise removal using wavelet can be expressed as follows:

- low frequency and high frequency coefficients of the image is obtained by using wavelet transform.
- Evaluate noise variance.
- Thresholding is applied on detail parts.
- Denoised image is obtain by applying Inverse wavelet transform.

Wiener filter (Linear filter) in the wavelet domain produce better results when gaussian noise is present in the image. However, this filter did not produce visually accepted result, but the filtering operation effectively decreases the MSE.

The another best method in Wavelet Transform based denoising is the non-linear method using thresholding. In this method, a threshold value is determined. Large wavelet coefficients are not disturbed and small wavelet coefficients in high frequency sub-bands are eliminated by using this value. Thresholding methods are used to eliminate unwanted values, to pre-serve significant coefficient values, and for noise elimination [10].

Histogram methods are used to evaluate distribution of intensity values in the image so that the valleys, peaks, and curves of the histogram can be obtained. Clustering-based methods is applied to clustered the image into different parts. The histogram of background and foreground can be represented as probability distribution function as two Gaussian distributions. Thresholding can be done by an entropy-based method.

b. *Non-Subsampled Contourlet Transform(NSCT) based enhancement*

The NSCT is the enhanced Contourlet transform, which may excellently solve the matter of artefact development within the increased curve image. Moreover, selecting the improvement perform and also the NSCT filter can directly influence the image improvement impact.

In [12], the input image is disintegrate into the NSCT domain with a low frequency, and a different high-frequency sub-bands. Linear transformation is considered for the coefficients of the low frequency sub-band. Adaptive thresholding methodology is employed for removing noise in the high-frequency sub-bands. Then, the inverse of NSCT is used to reconstruct sub-bands of low and high frequency into spatial domains. Finally, the fine details of the reconstructed image are enhanced by unsharp masking.

In [13], the NSCT and the enhancement function with nonlinear characteristic are used to improve the image quality. Initially, a sine gray-scale transform is considered as the factor to improve the image quality and this is a transform function of nonlinear nature. Second, the NSCT is employed to obtain both low frequency component and high frequency component. Then, the enhancement function is employed to the NSCT coefficients. Lastly, the NSCT is inversed to get the improved image.

The Contourlet transform is built by the Laplacian pyramid (LP) filter and directional filter bank (DFB). it has multi-direction, multi-resolution, and locality characteristics. The Contourlet transform is translation-variant due to its filter bank structure. Further, Contourlet transform can induce the artefact within the enhanced image. but the NSCT is built by the non-subsampled pyramid (NSP) and non-subsampled directional filter bank (NSDFB) it has the translational invariance and also good frequency selectivity and regularity.

The diagram of the NSCT is as shown in Fig.1. The decomposition levels are three and also the directional numbers are four, eight, and sixteen respectively.

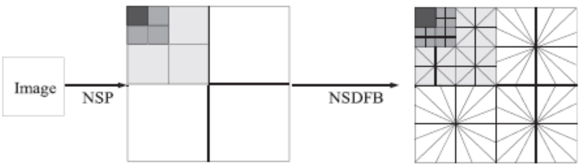

FIG. 1. The NSCT decomposition.

c. Threshold estimation

Selection of a threshold value for CT image denoising is a very difficult for edge enhancement and noise reduction. If threshold value is small, then noise will not be eliminated completely. If threshold is high value, then image becomes blurry. There are various algorithms used to select appropriate threshold value. There are three methods of threshold estimation are VisuShrink, SureShrink, and BayesShrink. VISUShrink is a non-adaptive global threshold, which has only one threshold value for complete image, this value is obtain from all pixel values in the image. This global threshold is used to all decomposition levels. The input image is over smoothed by using VisuShrink method.

SureShrink thresholding is based on a sub band adaptive threshold. A different threshold is obtained for each sub band using Steins unbiased risk estimator (SURE). BayesShrink utilizes a Bayesian mathematical framework and undertakes generalized Gaussian distribution for the wavelet coefficients in each detail sub band to obtain the threshold.

IV. MEASURES OF IMAGE DENOISING PERFORMANCE RESULTS

SSIM is Structural Similarity Index defined as:

$$SSIM(X,R) = \frac{(2\mu_X\mu_R + C_1)(2\sigma_{XR} + C_2)}{(\mu_X^2 + \mu_R^2 + C_1)(\sigma_X^2 + \sigma_R^2 + C_2)}$$

where C_1 and C_2 are predefined constants, μ_X, μ_R are the averages of X and R, σ^2_X, σ^2_R are the variance of X and variance of R respectively, σ_{XR} is the covariance between X and R. The values of SSIM is varies from −1 to 1. The value 1 shows good results.

The Image Quality Index (IQI) is:

$$IQI = \frac{4\sigma_{XR}\bar{X}\bar{R}}{(\sigma_X^2 + \sigma_R^2)((\bar{X})^2 + (\bar{R})^2)}$$

Where

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i,$$
$$\bar{R} = \frac{1}{N}\sum_{i=1}^{N} R_i,$$
$$\sigma_X^2 = \frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})^2,$$
$$\sigma_R^2 = \frac{1}{N-1}\sum_{i=1}^{N}(R_i - \bar{R})^2$$
$$\sigma_{XR} = \frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})(R_i - \bar{R})$$

The range of IQI is between 1 and −1. The value 1 shows that input image pixel is equal to output image pixel.

The Peak Signal to Noise ratio is:

$$PSNR = 10 \times log_{10}(\frac{255 \times 255}{MSE})$$

Where mean square error, is

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

Root mean square error can be given as:

$$RMSE = \sqrt{MSE}$$

Absolute Mean Brightness Error (AMBE) is given as

$$\mathrm{AMBE(x,y)} = |\mathrm{X}_m - \mathrm{Y}_m|$$

Where Xm is input image mean and Ym is output image mean. For the brightness preservation, The AMBE value should be very less.

Entropy is used to describe the input image texture.

Entropy Difference (ED) is given as $ED = SE(X) - SE(R)$.

Shannon entropy (SE) is given by following equation:

$$SE = -\sum_i X_i \log X_i^2.$$

DIV, difference in variances is given as

$$DIV = 1 - \frac{\sigma_R^2}{\sigma_X^2}.$$

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If the values of RMSE, ED and DIV closer to 0 indicates that the performance algorithm gives better results.

Where X is input image and R is denoised image

Table I gives various image enhancement methods, it's methodology, and different parameters.

Table I: image enhancement Techniques, It's Methodology

S.No	Reference	Methodology	Parameters measured	Remarks
1	[1]	Spatial domain method $$K = \frac{\sum_{i=1}^{i}\sum_{j=1}^{j} x(i,j)}{m \times n}$$ $$EI = \frac{[x - \min(x)] \times e^{K}}{[\max(x) - \min(x)]}$$	Universal Image Quality Index (UIQI)	Fast implementation due to normalization technique
2	[2]	Using DWT and SVD	Mean, STD, PSNR, WPSNR,QRCM	Transformation is applied only on low frequency image details.
3	[3]	Fusion rules applied on Gaussian filtered image and gradient image	Entropy,PSNR,SSIM.	low contrast image enhancement.
4	[4]	a non-local means (NLM) filter and correlation-based wavelet packet thresholding	PSNR, IQI, ED	two different detectors are used
5	[5]	Modified Haarwavelet transform and image fusion.	MSE, PSNR (dB), MI, UIQ	image fusion is used
6	[6]	low-rank sparse component de-composition and dictionary learning.	mutual information , Tsallis entropy, nonlinear correlation in-formation entropy	multi-modal medical images can be simultaneous fusion, denoising, and enhancement
7	[7]	fractional differential and directional derivative.	Mean, clarity, entropy.	The best order of the fractional differential is α=0.8
8	[8]	A dynamic unsharp masking using optimum wavelet based masking.	Absolute Mean Brightness Error (AMBE)	a dynamic unsharp masking technique
9	[9]	PWLS-ULTRA	RMSE, SSIM	for low-dose CT imaging

V. CONCLUSION

Computed Tomography images mainly used in medical for diagnostic purpose. The noise present in CT image mainly while acquiring the image and transmitting the image. The level of noise can be decreased and/or eliminated by applying suitable denoising technique. Therefore, appropriate image denoising can be applied to increase the image quality for mainly diagnosis purpose.

This paper discusses CT denoising techniques and various image quality parameters used to check the quality of denoised image such as SSIM, PSNR, MSE, RMSE, ED and DIV.

Only one image denoising method to CT image is not sufficient to obtain all important parameters with regards to noise decrease, edge protection, and strength. The techniques used to obtain CT imaging and CT imaging types are upgrading every day. Therefore, the denoising techniques used for CT images has to be modified and enhanced.

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