MEDICAL IMAGE ENHANCEMENT BASED ON NOISE REDUCTION USING ADAPTIVE WAVELET THRESHOLDING AND NON-LOCAL MEANS

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Abstract :
CT Images are most widely used for radiological diagnosis in medical examinations. The presence of artifacts and noise in images causes the difficulty in medical diagnosis. The noises are generally occurred and corrupt an image during its acquisition or transmission. Image denoising is one of the popular methods with an aim of noise reduction to retain images quality. A tradeoff between noise reduction and the preservation of actual detail features has to be made in the way that enhances the diagnostically relevant image content. Therefore, noise reduction is still a difficult task. Edges are of critical importance to the visual appearance of images. So, it is desirable to preserve important features, such as edges, corners and other sharp structures, during the denoising process.In this thesis, Dual-Tree Complex Wavelet transforms (DTCWT) based noise reduction technique is proposed to improve image quality where thresholding and Non-local means algorithm are applied. The Noisy medical image is decomposed using DTCWT, where approximation part is filtered using Non-local means filter and detail parts are filtered by the thresholding. By using the level dependent, the wavelet coefficients are calculated using optimal linear interpolation shrinkage function. Denoised image is acquired using inverse DTCWT. The value of the peak signal to noise ratio (PSNR) and Mean error are used as the measure of image visual quality. From study the experimental results and comparative study will demonstrates that the proposed method improves the image visual quality in respect of noise removal and edge preservation.

IndexTerms – DTCWT,NLM,Adaptive Thresholding,I-DTCWT.

I. INTRODUCTION

The influence and effect of digital images on modern society is unbelievable, and image processing is now a critical component in science and technology. In analysis methods and computer aided diagnosis, the rapid progress in computerized medical image reconstruction, and the associated developments, has propelled medical imaging into one of the most important subfields in scientific imaging. In Medical image processing, the area of interest is being raised. It comprises an extensive range of methods and techniques, initiating with the acquisition of images by exploiting specialized devices, image enhancement and analysis, to 3D model reconstruction from 2D images. For performing segmentation and for extracting important information an image is captured, digitized and processed in medical imaging. Usually, Medical images are of low contrast and due to various acquisitions they have a complex type of noise frequently, transmission storage and display devices are also because of application of diverse types of quantization, reconstruction and enhancement algorithms. The image processing techniques make it feasible, to extract meaningful information from medical images. The main objective of medical imaging is to acquire a high resolution image with as much details as possible for the sake of diagnosis. To achieve the finest possible diagnoses it is necessary thatmedical images be sharp, clear, and free of noise and artifacts. One of the major challenges in the study of medical imaging is noise removal in these digital images. Subsequently they could mask and blur important but delicate features in the images, the noise in medical images creates a problem; many proposed denoising techniques have their own problems. Medical image processing and analyzing focuses on three major research fields, such as Structural Imaging, Functional Imaging, and Molecular Imaging. Medical image enhancement technologies have attracted much attention since advanced medical equipments were put into use in the medical field. Enhanced medical images are desired by a surgeon to assist diagnosis and interpretation because medical image qualities are often deteriorated by noise and other data acquisition devices, illumination conditions, etc. Our targets of medical image enhancement are mainly to solve problems of the high level noise of a medical image. The noise present in the images may appear as additive or multiplicative components and the main purpose of denoising is to remove these noisy components while preserving the important signal as much as possible. In medical image enhancement there are many studies, mainly on gray scale transform and frequency domain transform. Frequency domain filtering can be used for periodic noise reduction and removal.

1.1 Computed Tomography (CT)

Computed tomography (CT), invented by Godfrey N. Hounsfield in 1972, was the first method that allowed generating non-overlapping axial slices of the internal structure of a human's body without opening it. Today, CT is associated with high efficiency in radiologic diagnostics and has become an important tool in medical examinations.Computed tomography (CT), originally known as computed axial tomography (CAT or CT scan) and body section roentgenography, is a medical imaging method employing tomography where digital geometry processing is used to generate a three-dimensional image of the internals of an object from a large series of two-dimensional X-ray images taken around a single axis of rotation. The word "tomography" is derived from the Greek tomos (slice) and graphein (to write). CT produces a volume of data which can be manipulated, through a process known as windowing, in order to demonstrate various structures based on their ability to block the X-ray beam. Although historically (see below) the images generated were in the axial or transverse plane (orthogonal to the long axis of the body), modern scanners allow this volume of data to be reformatted in various planes or even as volumetric (3D) representations of structures. Computed Tomography (CT) is a powerful nondestructive evaluation (NDE) technique for producing 2-D and 3-D cross-sectional images of an object from flat X-ray images. Characteristics of the internal structure of an object such as dimensions, shape, internal defects, and density are readily available from CT images. Shown below is a schematic of a CT system.Transmission computed tomography**.** Today the most widely used imaging modality is the x-ray transmission intensity projection or radiograph (known as “x-ray”).The difference between the x-ray (a simple two-dimensional projection image)and the x-ray computed tomography (known as “CT”) is that the latter is the result of mathematically reconstructing an image of a slice through the body from multiple x-ray transmission projection images taken at multiple angles around the body. The CT scanner is basically an X-ray device that scans the objects from all angles and records the density and thickness of the analyzed materials.The x-rays are generated by the interaction of accelerated electrons with a target material such as tungsten. The electrons are produced by a heated cathode and accelerated by applying a voltage between the cathode and a tungsten anode. The x-rays from tungsten are emitted from the x-ray tube placed one or more meters from patient.The x-radiograph is usually a film, not unlike a negative, which is darkened due to the interaction of the photons with the silver halide granules of the film. The image reflects the number or intensity of photons reaching the film but, as is the case for a conventional negative, the greater the intensity, the darker the radiography. However, traditional x-ray technique has many limitations. First of all, this method does not permit the distinction between various tissues, because of the small characteristic differences in x-ray attenuation. It cannot distinguish, for example, between muscles, ligaments or vessels, therefore their image cannot be captured by this method. Another major disadvantage is the superposition and compression of 3D information into a 2D image. Because of this, useful information is lost and the image detail of the analyzed object is only partially captured. The x-ray computed tomography is a more complete technique that adds a mathematical reconstruction theory of an object from its projections to multi-angular x-ray scanning. The x-ray CT machines use also an x-ray tube, but instead of being detected on film, the intensity is detected from an array of devices or tube systems, as shown in figure 1.1. The X-ray tube produces the x-ray energy that creates the CT image. The tube rotates around the human body in order to perform multiple exposures in a short-time and producing in this way a fan shaped beam.

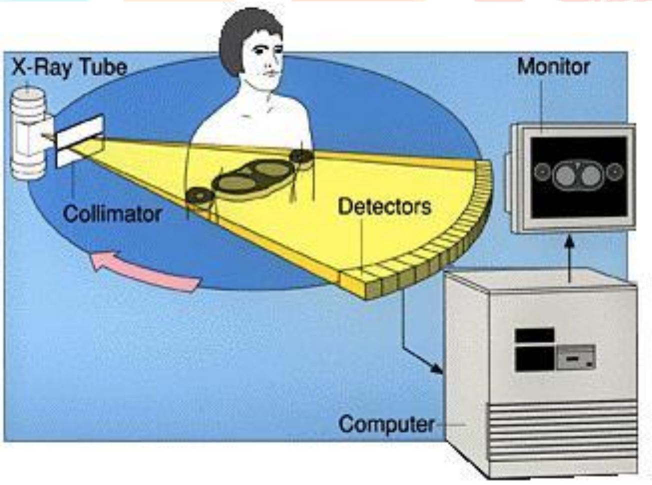

Fig 1.1: CT Scanning

As x-rays pass through the body, they are absorbed or attenuated at different levels, creating a profile of beams of different intensities. A detector, that further transforms the profile in an image, analyzes this profile. The computer tomography involves mainly the presence of a computer, which process the information received through the passage of an x-ray beam through an anatomical area. The CT creates images representing cross sectional slices of the exposed area. Each CT slice represents a specific plane, its thickness being called the z axis.X-ray imaging is mainly an anatomical procedure. The absorption of x-rays due to differences in elemental composition has an important effect for imaging bone or calcium deposits because this absorption process is proportional to the atomic number. Many factors affect the quality of the CT image produced, some of those factors can be regulated, some cannot. One of the factors that can be regulated is the slice thickness. Slice thickness is extremely important in CT because for example, thinner slices produce sharper images and on the other hand, the thicker the slice, the more flattening is necessary. If the slice thickness is big, the inaccuracies will be pronounced because the system approximates a 3D volume (a cube) to a 2D image (a square).

Another factor that affects the quality of a CT image is the field of view. It is essential to choose a correct field of view otherwise the final CT image could be too small or too big, with abnormalities hard to detect and precious information lost. An important role in obtaining an accurate CT image is played by the algorithm used for reconstruction, and this depends on the manufacturer of the tomograph. Beside the conventional computer tomography method, there are a few other methods that are based on the same principle: Helical CT, Multidetector CT and Electron Beam CT. The data acquisition process for helical CT traces out a spiral trajectory rather than a sequence of parallel ones; this method permits capturing a larger volume of the analyzed object in a very short period of time.

Multidetector CT method is similar to the previous one; it is in fact an improved helical CT. In this case, multiple parallel detector arrays record multiple beams simultaneously and allow multiple slice profiles to be acquired during a single spiral cycle. Electron beam CT is a specialized imaging application used usually in cardiac imaging because it gives the possibility to image body parts in motion This it is possible due to the fact that there is no mechanical rotation of the x-ray source (gantry) like in all the previous cases. Instead, the x-ray source consists of four parallel pairs of semicircular rings spanning around the patient. An electron beam is electromagnetically swept along one ring at a time, thereby creating a rotating fan beam of x-ray. The CT process consists mainly of 3 parts: data acquisition, image reconstruction and image display. All the views that form an image are processed by the computer and stored for later use. Some of these raw data are used in the creation of image data. The raw data are refined and analyzed and transformed in what are called image data. These image data are further transformed and create the final CT image.

The imaging system provides a shadowgraph of an object, with the 3-D structure compressed onto a 2-D plane. The density data along one horizontal line of the image is uncompressed and stretched out over an area. This information by itself is not very useful, but when the test component is rotated and similar data for the same linear slice is collected and overlaid, an image of the cross-sectional density of the component begins to develop. To help comprehend how this works, look at the animation below.A basic problem in imaging with x-rays (or other penetrating radiation) is that a two-dimensional image is obtained of a three-dimensional object. This means that structures can overlap in the final image, even though they are completely separate in the object. This is particularly troublesome in medical diagnosis where there are many anatomic structures that can interfere with what the physician is trying to see. During the 1930's, this problem was attacked by moving the x-ray source and detector in a coordinated motion during image formation. From the geometry of this motion, a single plane within the patient remains in focus, while structures outside this plane become blurred. This is analogous to a camera being focused on an object at 5 feet, while objects at a distance of 1 and 50 feet are blurry. These related techniques based on motion blurring are now collectively called classical tomography. The word tomography means “a picture of a plane”. In spite of being well developed for more than 50 years, classical tomography is rarely used. This is because it has a significant limitation: the interfering objects are not removed from the image, only blurred. The resulting image quality is usually too poor to be of practical use. The long sought solution was a system that could create an image representing a 2D slice through a 3D object with no interference from other structures in the 3D object.This problem was solved in the early 1970s with the introduction of a technique called computed tomography (CT). CT revolutionized the medical x-ray field with its unprecedented ability to visualize the anatomic structure of the body. Computed tomography was originally introduced to the marketplace under the names Computed Axial Tomography and CAT scanner. These terms are now frowned upon in the medical field, although you hear them used frequently by the general public.Images based on acquisition x-ray beam geometry, Computed Tomography can be alienated into 2 categories namely: fan beam and cone beam. An x-ray source and solid-state detector are mounted on a rotating gantry in fan-beam scanners. Data are acquired by transmitting a narrow fan-shaped x-ray beam through the patient. Hemorrhage and other lesions that may replicate stroke such as tumors, subdural/extramural hematomas and abscesses can be detected by Computed Tomography (CT). Especially for low-risk patients with a long life expectancy, Dose Reduction is a significant topic. However, reduction of the radiation dose will increase the amount of photon noise in CT images, which will degrade the image quality. Though there are numerous other effects that influence CT image quality, such as background noise and subject movement, photon noise contributes the most to CT image quality degradation. A clear relation between an increase in noise and a reduction in diagnostic accuracy and vice versa, i.e., a lower amount of noise will improve the diagnostic quality has been studied through these results.

1.2 Advantages

- Speed
- Relatively reduced radiation exposure to the patient
- Comparatively small scanning time
- The lungs can be pictured in less than a minute.
- CT totally prevents the superimposition of images of structures beyond the region interest.
- Dissimilarities between tissues that vary in physical density by below 1% can be perceived due to the inbuilt high-contrast resolution of CT.
- Data from a single CT imaging method containing either many adjoining or one helical scan can be perceived as images in the axial, coronal, or sagittal planes, based on the diagnostic action.
- Improved soft tissue contrast and cross-sectional imaging potential.
- The CT scan method is non-invasive and pain free, and is normally fast and comfortable for majority of patients.
- It is accurate because CT scan yields an extremely clear depiction of where a tumor or other problem is situated to a doctor and whether it has spread, it can assist the doctor in scheduling a biopsy, surgery, radiation or other therapy with better accuracy.
- The CT scan is the most comprehensive, and can yield the most comprehensive depiction of what's taking place within a patient's body to a doctor. They are valuable and broadly utilized in diagnosing cancer.

1.3 Motivation & Objectives

Digital image processing plays a key role in medical diagnosis. Medical images are obtained and analyzed to determine the presence or absence of abnormalities such as tumor, which is vital in understanding the type and magnitude of a disease. Unfortunately, medical images are susceptible to impulse noise during acquisition, storage and transmission. Hence, image denoising is a primary precursor for medical image analysis tasks. Conventional smoothening filters and median filters are the most popular filters for noise reduction in digital images. But, a single smoothening or median filter is not enough for completely removing the noise, especially when the noise level is high. Also, it may not preserve image details such as edges during filtering. This is a serious issue in medical image analysis because loss of image details results in inaccurate image analysis which may prove fatal to the life of a person. Hence, many methods have been proposed for noise removal from medical images. While some of these methods use complicated formulations, others require deep knowledge about image noise factors. Hence, a simple noise reduction method that removes noise well and preserves image details without relying on image noise factors is desirable. Applying a set of denoising and enhancement filters successively on a noisy image may remove noise and preserve image details much more efficiently than a single median or smoothening filter. Image denoising imposes a compromise between noise reduction and preserving significant image details. To achieve a good performance in this respect, a denoising algorithm has to adapt to image discontinuities. Geometrical features in images, like edges and contours, play one of the most important roles in the human visual system, since they carry most of the perceptual information. An efficient image representation has to be capable of precise modeling and of providing a sparse description of this geometrical information. The major challenges for noise reduction in CT Image are:

- Flat regions should be flat
- Image boundaries should be preserved (no blurring)
- Texture details should be preserved
- Global contrast should be maintained
- Artifacts should not be appeared**.**

1.4 Aim of the Thesis

Noise is undesired information which added into medical images which creates the problem to find the diagnoses. From various literatures, it was observed that generally medical images are degraded with Gaussian noise due to mathematical computational errors. It was also analysed that the radiations to create CT images are harmful for the patients. High radiation dose gives more good quality in terms of noise but these high radiation doses are harmful for the patient. While, low dose CT images are degraded with Gaussian noise.With this motivation, the aim of the thesis is to improve the CT image quality which is degraded through the Gaussian noise. To improve the image quality, noise reduction techniques are used over lower dose images and noise is reduced with preserving all clinically relevant structures. We proposed an approach which is used to enhance a medical image (CT image) by using Nonlocal means filter and wavelet transform. In this work, unwanted noisy components can be threshold without affecting the significant features of the image. We calculate PSNR (Peak Signal to Noise Ratio) and MSE (Mean Square Error) by using these two wavelets and then compare the resultants.

II. IMAGE DENOISING

Filtering is perhaps the most fundamental operation of image processing and computer vision. In the broadest sense of the term "filtering", the value of the filtered image at a given location is a function of the values of the input image in a small neighborhood of the same location. For example, Gaussian low-pass filtering computes a weighted average of pixel values in the neighborhood, in which the weights decrease with distance from the neighborhood center. Although formal and quantitative explanations of this weight fall-off can be given, the intuition is that images typically vary slowly over space, so near pixels are likely to have similar values, and it is therefore appropriate to average them together. The noise values that corrupt these nearby pixels are mutually less correlated than the signal values, so noise is averaged away while signal is preserved. However, the assumption of slow spatial variations fails at edges, which are consequently blurred by linear low-pass filtering. How can we prevent averaging across edges, while still averaging within smooth regions?Many efforts have been devoted to reducing this undesired effect. Edge-preserving smoothing is one of image processing techniques that smoothens away textures whilst retaining sharp edges. When we need to preserve edge information and at the same time preserve the edges. Even when uniform smoothing does not remove the boundaries, it does distort them. Bilateral filtering is a simple and non-iterative image smoothing scheme for edge-preserving, by means of a nonlinear combination of nearby image values. It extends the concept of Gaussian smoothing by weighting the filter coefficients with their corresponding relative pixel intensities.Pixels that are very different in intensity from the central pixel are weighted less even though they may be in close proximity to the central pixel. This is effectively a convolution with a non-linear Gaussian filter, with weights based on pixel intensities. This is applied as two Gaussian filters at a localized pixel neighborhood, one in the spatial domain, named the domain filter, and one in the intensity domain, named the range filter.The denoising is an operation to estimate clean image from a degraded or noise affected image and this process is required to achieve visually pleasant and also to get quality reconstruction of image. The basic filtering methods are classified into spatial domain method and Transform domain method. For both domains, Linear and non-linear filtering methods are used.

Digital images plays vital role in day to day applications. Noise is introduced in the images during transmission and acquiring from cameras. Any unwanted signal and its electrical interference and blur due to camera movement, environmental conditions like rain, snow, and sampling and quantization errors could be considered as noise. In other terms one person's signal might be another person's noise. The noise complicates the post process of compression and other image processing tasks. So it becomes very essential to remove noise for better interpretation by human eyes. There are two types of noise namely multiplicative noise and additive noise. The multiplicative noise is generally complex model and caused by de-phased echo signals from scatters.

III. PROPOSED TECHNIQUE

With this assumption the medical image is corrupted by Gaussian noise with zero mean and variance as equation (4.1), the noisy image can be expressed as:

$$B(i,j)s = A(i,j)s + \eta(i,j)s \quad \ldots\ldots(4.1)$$

Where, $\eta(i,j)s$ is noise coefficient, $A(i,j)s$ is noiseless image and $B(i,j)s$ is noisy image.

Noise reduction architecture is proposed as shown in figure 4.1, where following steps are processed as:

Step 1: Perform dual tree complex wavelet transform (DT-CWT) of medical image corrupted by Gaussian noise to obtain approximation and detail parts.

Step 2: Estimate decomposition level by using log energy.

Step 3: Apply adaptive wavelet based thresholding over the detail parts.

(i) Compute the threshold value for each sub-band in all levels.

(ii) Apply Threshold to all sub-band's coefficients using the optimum linear interpolation threshold function.

Step 4: Apply Non-local Means method over approximation parts.

Step 5: Perform inverse dual tree complex wavelet transform (Inverse DT-CWT) using step 3 & 4.

In the above algorithm, the two way denoising method is used. One part (approximation) is denoised by Non-local means and other part (detail) is denoised by thresholding using optimum linear interpolation method. Using both results, reconstruction is done to get the final denoised image.

The wavelet decomposition is done with following steps:

1) Firstly, set the maximum number of levels.

2) For each level, decompose into four sub-bands (child nodes).

3) Compute cost value (by using log energy) for each sub-band for each level.

4) In top down approach manner, Check the cost value:

a) If the cost of parent node is greater than total cost of child nodes; do continue.

b) Otherwise; eliminate children nodes.

5) End the process, if there is no node to decompose.

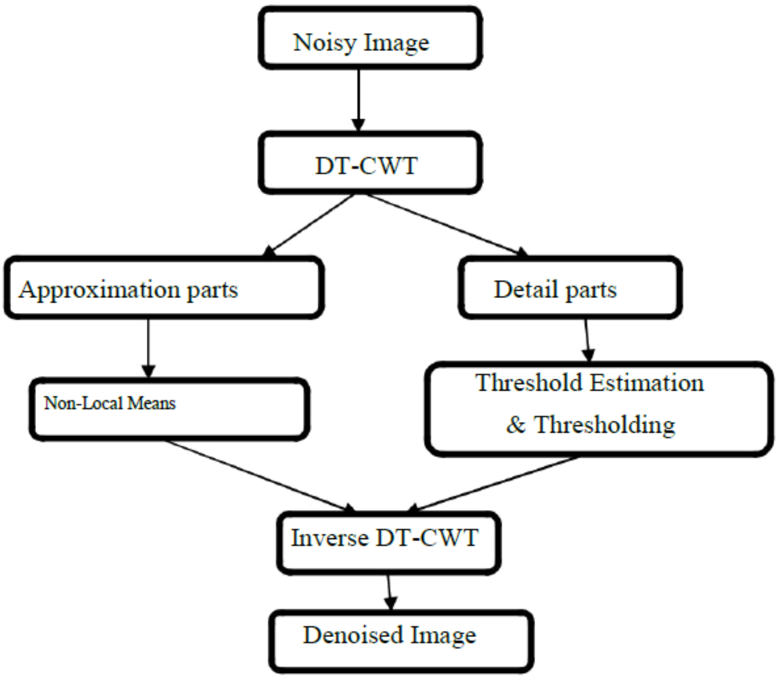

Figure 3.1:Proposed Noise Reduction Architecture

IV. RESULT AND TABLES

Images

Figure 1: Original CT Image Data Set

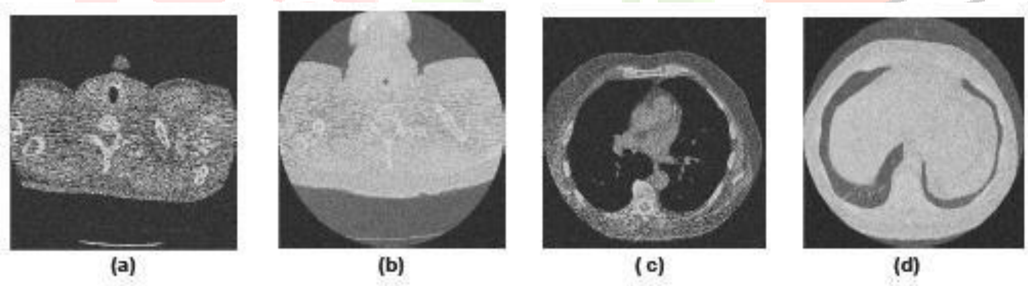

Figure 2: Noisy CT Image Data Set (σ =20)

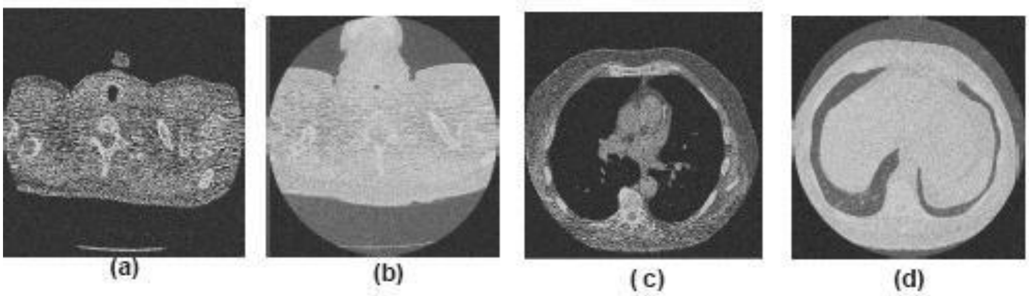

Figure 3: Results of Wavelet Based Denoising

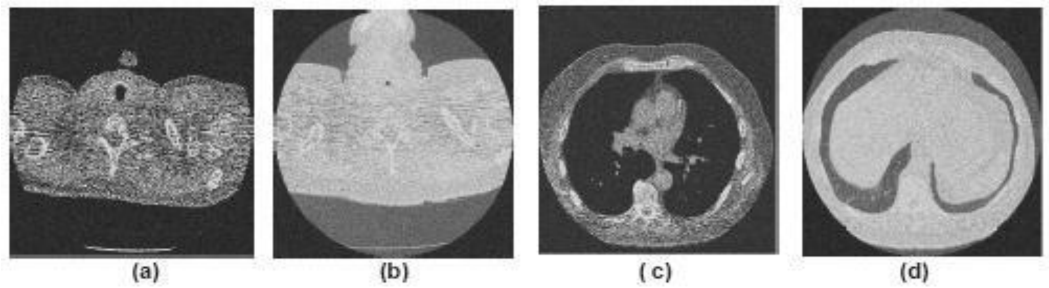

Figure 4: Results of Dual Tree Based Denoising

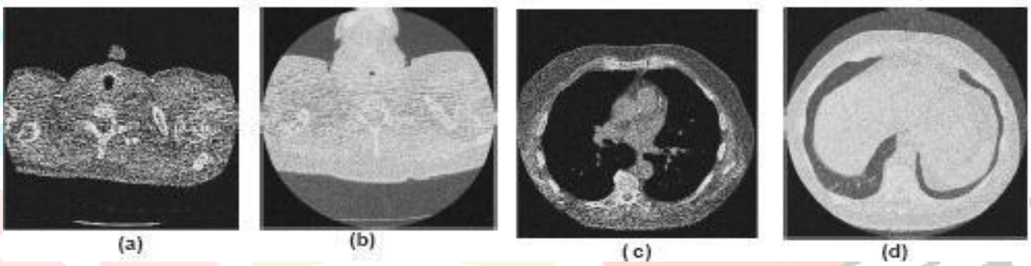

Figure 5: Results of Proposed Scheme

Table 1: PSNR & Mean Error Table

		Wavelet based denoising		Dual tree based denoising		Proposed Method	
MedicalImage Dataset	Noise (σ_η)	PSNR	Mean error	PSNR	Mean error	PSNR	Mean error
CT 1	10	31.49	0.1910	32.33	0.1038	**33.37**	**0.0117**
	20	29.44	0.1992	30.41	0.1102	**31.20**	**0.0571**
	30	27.70	0.2280	28.26	0.1427	**29.74**	**0.0886**
	40	22.62	0.2663	23.35	0.2113	**25.30**	**0.0942**

CT 2	10	31.49	0.1143	32.54	0.1030	**33.49**	**0.0209**
	20	28.14	0.1406	30.40	0.1169	**31.15**	**0.0588**
	30	26.86	0.2577	27.69	0.1536	**28.04**	**0.0735**
	40	21.65	0.2837	22.15	0.2242	**24.60**	**0.0941**
CT 3	10	30.10	0.1662	31.04	0.1002	**32.74**	**0.0231**
	20	28.32	0.1992	29.94	0.1022	**30.28**	**0.0519**
	30	25.99	0.2209	26.87	0.1080	**27.69**	**0.0878**
	40	22.60	0.2991	23.46	0.1629	**25.59**	**0.0927**
CT 4	10	31.51	0.1177	32.15	0.1025	**33.48**	**0.0119**
	20	29.01	0.1688	30.10	0.1294	**31.06**	**0.0391**
	30	26.31	0.2574	27.13	0.1544	**28.29**	**0.0639**
	40	21.72	0.2702	22.97	0.1792	**24.69**	**0.0819**

V. CONCLUSION

The proposed method is applied on the basis of Wavelet thresholding and NLM filtering. The resultant images is of good quality for clinical diagnosis and may be supported for clinical applications by providing further control over image quality and analysis

VI. REFERENCES

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