Differential Mean Deviation Factor based Contrast Enhancement Technique Using DWT-SVD for Non-Contrast CT Scan Images

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Abstract: In proper clinical analysis and diagnosis of a patient, accurate visual representation of CT scan images plays a vital role. Due to technical constraints and poor imaging device, sometimes low contrast images can be obtained. To interpret and analyzed the minute details present in the image, the image needs to be enhanced appropriately. This proposed novel low contrast enhancement technique rely on the singular value decomposition (SVD) with discrete wavelet transform (DWT) for improving the minute visual information present in a image as well as retaining the mean brightness. By scaling the values of the singular matrix properly these existing SVD based techniques enhances the contrast of image but the contrast in case of the original CT scan image is too low and hinder proper enhancement result in poor analysis. In this suggested algorithm, the proposed differential mean-deviation factor properly equalized the singular matrix. Introduction of this parameter adjusted the singular value matrix in such a way that proper contrast enhancement is attained. Results of the simulation also reveal that the suggested approach also balanced the brightness of the picture more reliably and increases the contrast comparatively with negligible visual artifacts. It outperforms traditional methodologies of equalization of images such as GHE (Global histogram equalization) and LHE (local histogram equalization). Our proposed algorithm is evaluated and compared using different CT scan images and different algorithms based on SVD and DWT but the inclusion of our proposed factor mean deviation provides a niche over the existing ones in terms of subjective and objective analysis.

Keywords: Contrast Enhancement, CT Scan, Discrete Wavelet Transform (DWT), Global Histogram Equalization (GHE), Local Histogram Equalization (LHE), Singular Value Decomposition (SVD).

1. Introduction

This era of global technical advancement medical images are playing a very crucial role in diagnosing patients suffering with different ailments and diseases. These images give a clear information about the suffering and helps the clinical body to examine and providing the right solution. Though different advanced technologies are there to capture the problem domain of the patients and produce them as visually clear digital images but still due to several factors, they are not able to produce a satisfactory well contrast image for proper diagnosis. These factors are like poor lightning conditions, unsuitable condition of the patients and due to technical issues with imaging device (Al-Ameen Z et al., 2015). In the field of medical sciences, CT images play a very vital role in providing essential information regarding anatomy, pathology for proper diagnosis. Some particular parts of the body like liver whose CT scan images are generally are of low contrast are needed to be enhanced before diagnosis and sometimes some external agents were also infuse into the body to get clear pictorial representation but that also got restricted depending upon the patient's condition (Liang Y. et al.,2009).

The science of image processing has earned widespread demand around the community of research and engineering sectors such as health care, remote sensing, security etc (Frosio I.,2006; Yang Y, 2010; Al-Juboori R.A,2017; Bhandari A. et al.,2014). Image Enhancement is one of the important field of image processing used to improve the visual characteristic of an image needed for a specific or different intended applications. Now a day's many enhancement techniques based on optimization algorithms have been developed. Researchers have proposed different enhancement algorithms. These enhancement algorithms are distinguished in two different such as Spatial (or pixel Intensity) domain and Frequency (or Transformation based) domain (Huang S-C et al., 2013; Tang J et al., 2003). Many algorithms were intended for specific applications whereas some algorithms were designed for generalized use. These enhancement techniques play a very crucial role in visualizing and enhancing the non contrast CT images to provide suitable support to medical image processing applications.

One of the most common contrast enhancement algorithms is GHE (Global Histogram Equalization) technique. This is a efficient and simple approach of enhancing the contrast of an image by spreading the dynamic pixel intensity distribution to a wider range to achieve the objective of enhancement of an image. Though LHE (Local Histogram equalization) also exist but due to sub-blocks overlapping issue its complexity increases. Overall both of these techniques are very much efficient in improving the contrast of an image but due excessive distribution of intensities over the dynamic range unnatural artifacts appears in the enhanced image. That's why GHE and LHE are not suitable for many intensive applications of image processing but can be used in preprocessing stages.

Above mentioned functionalities drawback issues were greater taken care by many techniques proposed such as BBHE (Brightness Preserving Bi-histogram equalization) (Kim Y-T, 1997), DSIHE (Dualistic Sub Image Histogram Equalization) (Wang Y et al., 1999). Both of these techniques utilize histogram with mean and median parameters of the intensities. These techniques work well with quasi-symmetrical distribution-based histograms. As many image histograms always not having this property hence fails to provide adequate enhancement. This problem is well overcome by dynamic histogram-based techniques such as Dynamic Histogram equalization (M. Abdullah-Al-Wadud et al., 2007) and Brightness Preserving Dynamic Histogram Equalization (BPDHE) (Haidi Ibrahim et al. 2007), but again due to higher computational and complexity features while solving 2-dimensional histogram became unsuitable to provide satisfactory image contrast enhancement.

Researchers were continuously putting their efforts to utilize the features and characteristics of singular value decomposition (SVD) and Discrete wavelet transform (DWT) to obtain good promising techniques for image enhancement.

The enhancement techniques based on SVD equalizes the intensity information provided by singular value matrix to enhance the visual information of the images (H. Demirel et al., 2008). The enhancement produced by the SVD is substantially improved by the features of DWT (Discrete wavelet transform). Conjuncture algorithm based on DWT-SVD (H. Demirel et al., 2010) uses the approximate intensity information of LL sub-band obtained from DWT and then singular value decomposition has been done to obtain the intensity information matrix, on computing this intensity information matrix, image enhancement has been done. Though this DWT-SVD is showing promising outcome compared to SVD technique but producing some blurring effect at the contour of the objects present in the image. Hence DCT-SVD (A.K. Bhandari et al.,2011) has been proposed to contain the limitation. In DCT-SVD based technique, the image is transformed into different frequency bands low, medium and high. As most of the information is related to lower frequency band, hence it has to be extracted out to process with SVD to obtain enhance image. How much percentage of lower bands to be extracted created the visual imparity of information about minute objects in the image. More over as the edge information is lying on the higher frequency band, they remain as it is but not got enhanced.

In this work, we proposed a novel technique based upon the statistical values (Mean and Standard deviation) of the original and corresponding GHE image utilizing the DWT and SVD to obtain a better enhanced image compared to previous existing algorithms DCT-SVD and DWT-SVD.

2. Proposed Technique

Quality of CT Images generally get reduce due poor lightening conditions around the scene and also due to medical constraints during imaging, because of which most of the informative pixels intensities get merged with the background. Our primary objective is to extract all vital information about small objects present in the scene keeping their natural texture and color as far as possible.

The algorithm for the proposed technique using DWT and SVD is clearly shown below in Figure 1 and details about each step are discussed explicitly stepwise.

- The images captured in real scenario are in RGB format, which are highly correlated among themselves. So first the image is converted into RGB to YCbCr format. Where Y represents the intensity information of the image and Cb, Cr represents the actual current blue and current red composition in an image.
- The original image intensity Y is then processed through global histogram equalization technique to get equalized intensity Y_{eq}.
- Calculation of enhancing Mean-Deviation factor (F_{MD}): This factor plays a very crucial role in our proposed contrast enhancement algorithm.

$$\text{Differential-Mean-Deviation-Factor}=\frac{\text{Mu1-Sd1}}{\text{Mu2-Sd2}} \qquad (1)$$

- Mu1, Sd1 and Mu2, Sd2 indicates the Mean and standard deviation of the original Y intensity image and Global histogram equalized Y intensity image respectively. This Mean-Deviation ratio will be used to transform the intensity information present in singular decomposition matrix.
- Then Y is decomposed into different frequency bands using DWT2. DWT decompose the image into different sub-bands such as LL, LH, HL and HH. The LL sub-bands approximate the intensity information in DWT.
- This LL sub band is passed through SVD and obtained the approximate singular matrix. SVD (Singular value decomposition) is a versatile tool used for image compression, extraction of features, in recognition techniques as well as in enhancement of contrast of an image. Usually SVD dealt with illumination related to an image.

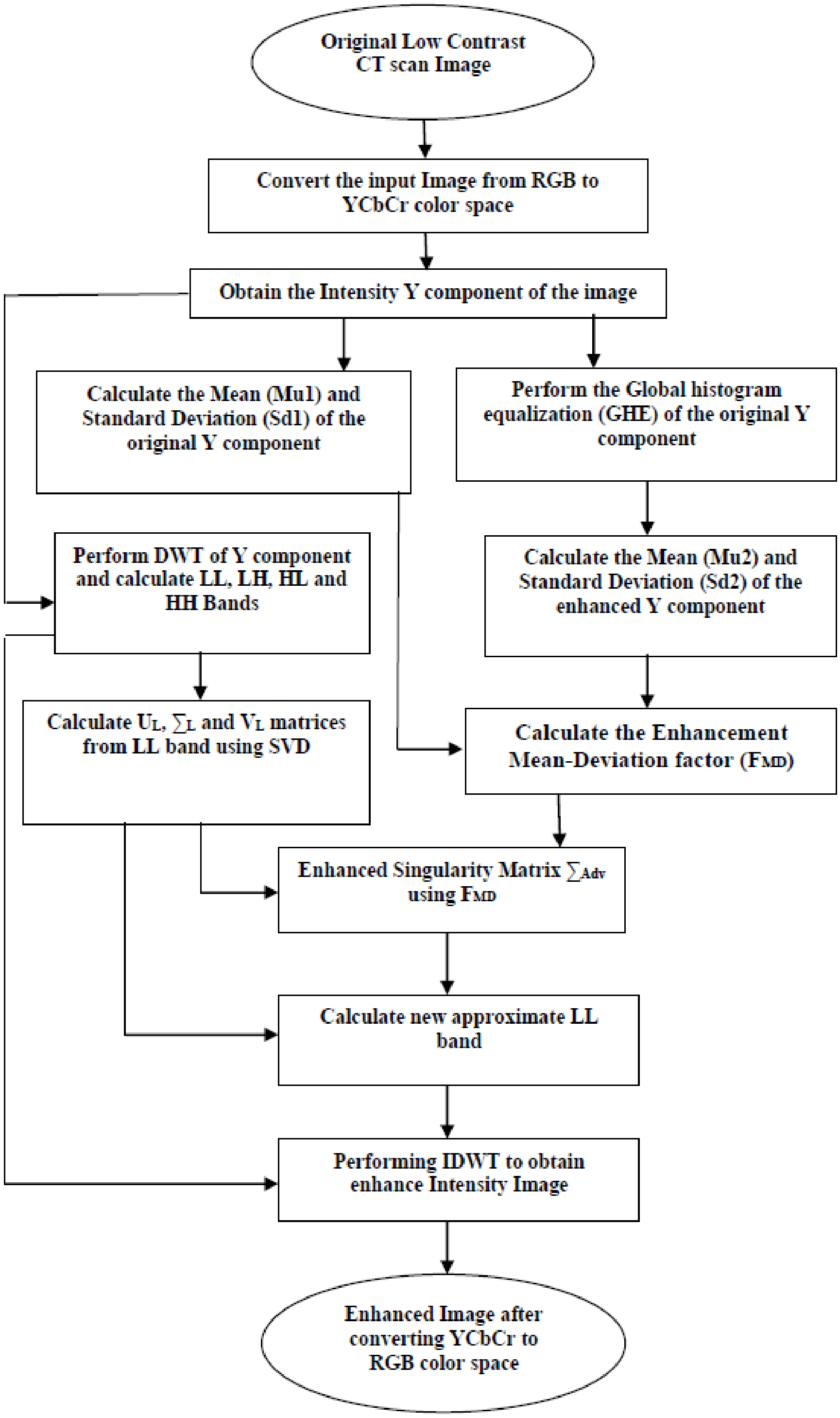


Figure 1. Flowchart of the Proposed Low Contrast Enhancement Algorithm

In matrix form SVD can be represented as

$$I = U_I * \Sigma_I * V_I^T \quad (2)$$

Hanger and aligner are the two orthogonal matrices are represented by UI and VI . ∑I is the singular vector consisting of information related to intensity of pixels in an image. Any changes we do perform on ∑I simply bring intensity transformation in an image. So this matrix is used contrast enhancement of an image or in other words used for image equalization.

- New Singular approximate matrix is obtained by
- $\sum_{new}$ =Mean deviation factor $(F_{MD}) * \Sigma_I$ (3)
- Now an enhanced approximate LL subband is formed using $\sum_{New}$
- $LL_{New} = U_{Original} \sum_{New} (V_{Original})^T$ (4)
- On performing the inverse wavelet transform using LLNew along LH, HL, and HH, we get the new intensity transform matrix YTrransform.
- Finally using this YTransform, Cb and Cr, the image is converted from YCbCr to RGB format to obtain the enhanced contrast image.

3. Qualitative and Quantitative Result Analysis

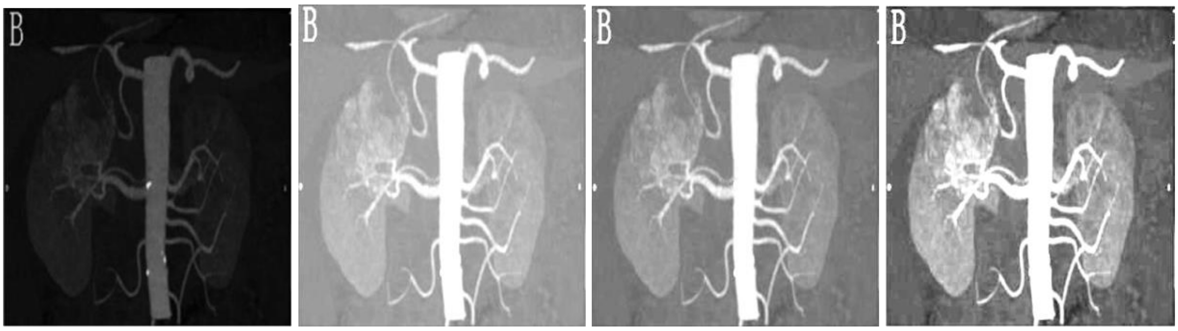
For better visual clarity of hidden, unclear entities in a CT scan image, contrast and brightness should be enhanced appropriately. Contrast enhancement of the image can be achieved by spreading the intensities over wider range; if the pixels got spread up by more amounts in the dynamic range then final output image got a white faded look. Hence it's become very important that spreading should be done by an enhancement algorithm through a controlled manner so that maximum possible contrast enhancement can be achieved along with preservation of edges. This objective of controlling the enhancement aspect is taken care by differential mean-deviation factor (FMD). In this proposed work, the algorithm is implemented using software MATLAB R2013a. After evaluation the qualitative result has been compared along with quantitative result using two existing approaches DWT-SVD based enhancement algorithm (H. Demirel et al.,2010) and DCT-SVD based enhancement algorithm (Bhandari A K et al., 2011).

For analysis purpose we have used five non contrast CT scan images of Neck, brain, prostate, kidney and ovary as shown in Figure 2-7. These images were developed using the 0.78 x 0.78 (in-plane resolution), 1.25mm (Slice thickness) with tube current and voltage of 200mAs and 140kV respectively.

Qualitative analysis reflects the visual perception of the outcome enhanced image. The original CT scan images and their enhanced outputs are shown in Figure 2-Figure7. The enhanced output images indicate our proposed enhancement technique is well suited for non contrast images and can able to provide more visibility and enhancement to the features hidden in lower part of the dynamic range compared to other techniques. DWT-SVD increases the contrast of the image but remain confine in the lower part to a great extend and DCT –SVD technique brings a significant improvement in the contrast but shifted more towards the bright range of the dynamic scale. Well the proposed algorithm utilizes the statistical feature of the original image along with the global histogram equalized image in a balanced way to give a better enhancement covering maximum region of the dynamic range while keeping the edge information intact.

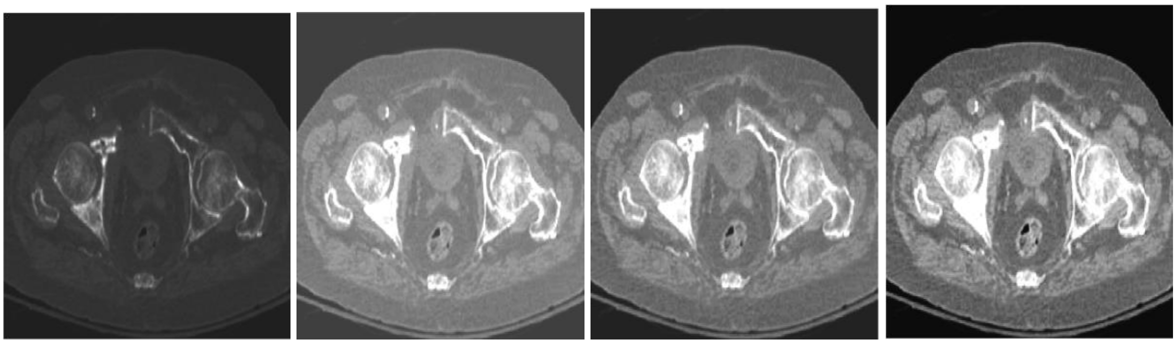
The visual clarity and human perception is validated by qualitative analysis while the quantitative analysis measures the amount by which the qualitative analysis validated the obtained enhancement result (Panetta K et al., 2011). The parameters used here for the quantitative analysis are PSNR (peak signal to noise ratio, Entropy, Standard deviation and IEM (Measure of Enhancement). These parameters always correlate with the subjective measure while evaluating the contrast enhancement (Jaya V L et al., 2013). The qualitative results are shown in Table 1 -4.

Peak Signal to Noise ratio (PSNR) is a quantitative parameter needs to measure the quality of the contrast enhanced image compared to the original image. On comparing the output image to the original image, the enhanced image is always assumed to be noisier as intensities got spread over the large dynamic range to produce contrast effect (Celik T et al., 2016; Jaya V L et al., 2013). Hence the value of PSNR decreases with increase in the contrast. The simulation result clearly reflects that quality of the enhanced image. Empirical simulation shows average PSNR value of proposed approach is 41.32% lesser than DWT-SVD and 19.19% less compared to DCT-SVD.



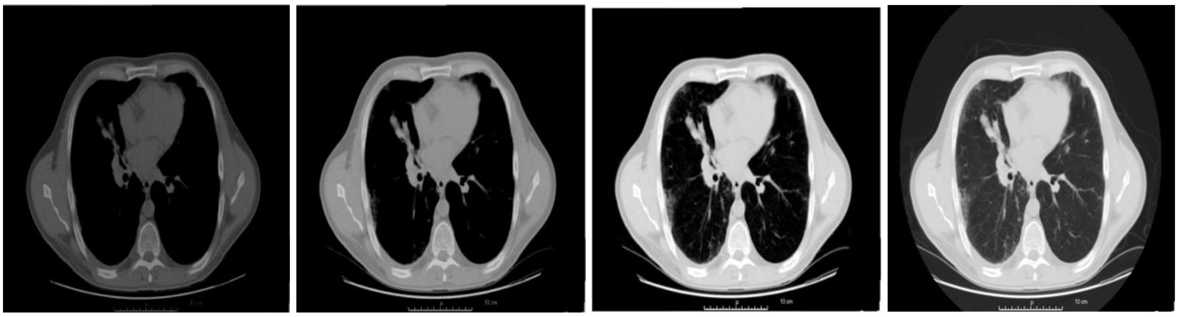
(a) (b) (c) (d)

Figure 2. Subjective Analysis of Non-Contrast Kidney CT Scan Image (a) Original Image (b) Enhanced Image Using DWT-SVD (c) Enhanced Image Using DCT-SVD (d) Enhanced Image using Proposed Technique



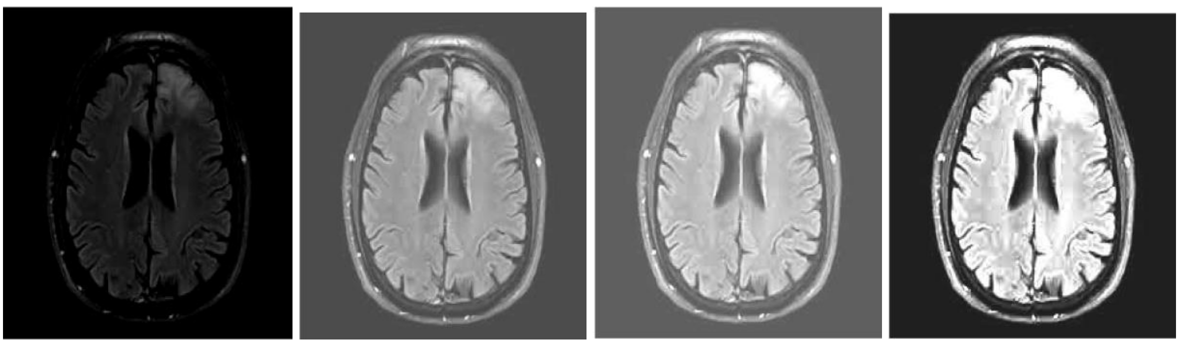
(a) (b) (c) (d)

Figure 3. Subjective Analysis of Non-Contrast Prostate CT Scan Image (a) Original Image (b) Enhanced Image Using DWT-SVD (c) Enhanced Image Using DCT-SVD (d) Enhanced Image Using Proposed Technique



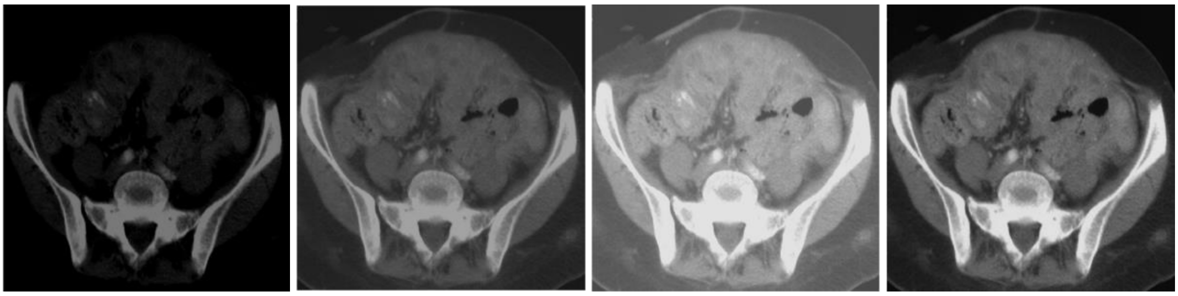
(a) (b) (c) (d)

Figure 4. Subjective Analysis of Non-Contrast Chest CT Scan Image (a) Original Image (b) Enhanced Image Using DWT-SVD (c) Enhanced Image Using DCT-SVD (d) Enhanced Image Using Proposed Technique



(a) (b) (c) (d)

Figure 5. Subjective Analysis of Non-Contrast Brain CT Scan Image (a) Original Image (b) Enhanced Image Using DWT-SVD (c) Enhanced Image Using DCT-SVD (d) Enhanced Image Using Proposed Technique



(a) (b) (c) (d)

Figure 6. Subjective Analysis of Non-Contrast Ovary CT Scan Image (a) Original Image (b) Enhanced Image Using DWT-SVD (c) Enhanced Image Using DCT-SVD (d) Enhanced Image Using Proposed Technique

Entropy usually measures information content of an image, it means the visual entities present in the image are more clear and distinct. For a good contrast enhanced image the value of entropy is always higher. In this proposed approach the value of entropy is 15.22% more compared to DWT-SVD and 8.2% more compared to DCT-SVD.

Table 1. Simulation Result of PSNR (Peak Signal to Noise Ratio) Values of Different Non-Contrast CT Scan Images Using Enhancement Techniques

Non-Contrast CT SCAN Images	DWT-SVD	DCT-SVD	Proposed
Chest	16.6753	10.4881	9.4357
Brain	7.7781	6.9582	6.5873
Prostate	11.4215	11.3085	6.2992
Kidney	6.7582	6.4551	6.2429
Ovary	13.9598	12.5241	11.4813

Standard Deviation (SD) of an image shows the amount of intensity values being covered by the image pixels in the dynamic range. If the spread of the pixels are more means more is the contrast. Higher value of SD is a clear indicator of good enhanced image. In our proposed approach the average SD is about 38.37% higher compared to DWT-SVD and 23.52% higher compared to DCT-SVD.

Table 2. Simulation Result of Entropy Values of Different Non-Contrast CT Scan Images Using Enhancement Techniques

Non-Contrast CT SCAN Images	DWT-SVD	DCT-SVD	Proposed
Chest	3.5270	4.7739	5.9877
Brain	4.9223	5.0860	5.2664
Prostate	5.7698	6.0362	6.2992
Kidney	5.9185	6.2199	6.7521
Ovary	6.5141	6.7436	7.1334

Table 3. Simulation Result of Standard Deviation of Different Non-Contrast CT Scan Images Using Enhancement Techniques

Non-Contrast CT SCAN Images	DWT-SVD	DCT-SVD	Proposed
Chest	55.7624	70.1820	77.2588
Brain	35.8280	41.9340	75.8448
Prostate	39.5531	49.0302	57.7553
Kidney	27.2786	34.7860	48.8408
Ovary	30.3682	38.3377	46.6233

Table 4. Simulation Result of IEM of Different Non-Contrast CT Scan Images Using Enhancement Techniques

Non-Contrast CT SCAN Images	DWT-SVD	DCT-SVD	Proposed
Chest	1.4429	1.6342	1.8314
Brain	1.5740	2.0764	3.4320
Prostate	1.4762	1.8387	2.3853
Kidney	1.2020	1.4743	2.4169
Ovary	1.1910	1.3978	1.6764

IEM (Measure of Enhancement) (Jaya V L et al., 2013) is a figure of merit represents enhancement in the contrast of an image. Higher value indicates the image contrast is more and well perceived by human visual system. The value of IEM for proposed differential mean-deviation factor-based approach is 41.36% greater than DWT-SVD and 28.28 % greater than DCT-SVD.

Table 5. Average Time Taken to Compute the Enhancement of Low Contrast CT Scan Images using Different Techniques

	Average Computational Time (in secs)		
	DWT-SVD	**DCT-SVD**	**Proposed**
Low Contrast CT scan Images	0.7325	2.2365	0.6254

More over the average computational time needed to obtain the enhanced image based on proposed mean deviation factor approach is 0.6254 seconds whereas the DWT-SVD takes about 0.7325 seconds and DCT-SVD based approach takes around 2.2365 seconds. The computation time of DCT-SVD is high because it needs to compute DCT while processing. Above empirical analysis clearly supports that our approach is more computationally efficient compared to DWT-SVD and DCT-SVD based enhancement technique.

The objective parameters comparison for different scan images chosen for contrast enhancement using different techniques such as DWT-SVD, DCT-SVD and proposed technique are shown below in Figure .7.

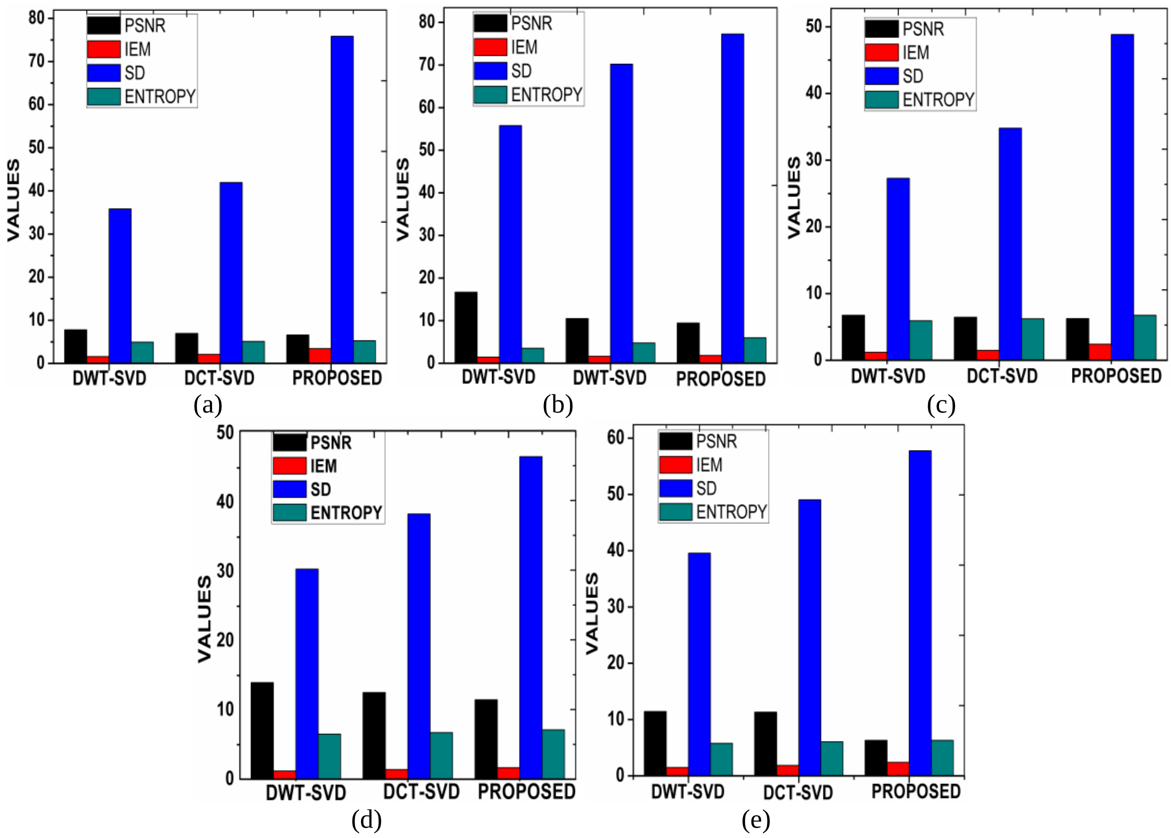


Figure 7. Comparison of Different CT Scan Images Using Different Techniques and their Corresponding Objective Parameters Values

The above simulation result clearly reveals that this novel proposed method not only enhances the contrast of the low contrast CT scan images but also delivered the result in a very low computation time. Need of distribution of the intensity over the span of dynamic range is balanced is well taken care by the proposed algorithm over the existing algorithm DWT-SVD and DCT-SVD.

4. Conclusion

This research work proposed is an attempt to use successfully the statistical feature of an image to produce a novel contrast enhancement technique. The property of every image lies on its statistical features. The proposed enhancing mean-deviation factor-based DWT-SVD method dynamically enhanced the dark non contrast CT scan images to a significant level giving relieve from the constraints raised during CT scan. The singularity matrix which is being modified by the differential mean deviation factor plays a very vital role. The amount of transformation needed is adjusted properly by proposed technique. Evaluation and comparison has been done with two state-of-art enhancement techniques. The empirical result clearly projected the niche of success achieved compared to the existing enhancement techniques. More over due to the much less computational time needed for processing gives and added advantage. But still, lots of factors like minimum save distance to perform scanning and patient condition, open the doors for more needed research on this field of image processing.

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