Low Contrast Image Enhancement using Wavelet Transform based Algorithms: A Literature Review

Namita Naik, Dr. Agya Mishra

Abstract— **Image Enhancement deals with enhancing the image so that it provides more details. Since image clarity is very easily affected by lightening, weather or equipment that has been used to capture the image. These conditions may lead to image suffer from poor contrast and loss of information. The main purpose of enhancement is to bring out detail that is hidden in image or to increase contrast in a low contrast image. This paper presents a literature review ofsome Image Enhancement algorithms in combination with wavelet transform such as DWT(discrete wavelet transform), SWT(singular wavelet transform), UWT(undecimated wavelet transform).This paper concludes that the algorithm using UWT gives better result and may be the field of research.**

Index Terms— **AHE (adaptive histogram equalization), Image Enhancement, DCT, DSR (dynamic stochastic resonance), DWT, SVD (Singular value decomposition, SWT,UWT**

I. INTRODUCTION

Image enhancement is to improve the interpretability or perception of information in images to provide better input for other automated image processing steps. As a result, many techniques have developed known as image Enhancement techniques to recover the information in an image. . The enhancement methods can be broadly categorized into following two methods:

1. Spatial Domain Method
2. Frequency Domain Method

The spatial domain techniques, directly operates on pixels of an image. The pixel values are manipulated to achieve desired enhancement [9]. The gain of spatial based domain technique is that they conceptually simple to understand and the complexity of these techniques are low . But these techniques have difficulty in providing sufficient robustness and imperceptibility requirements. In frequency domain methods, the image is transferred into frequency domain. It means that, the Fourier transform of the image is computed first. The result of Fourier transform is multiplied with a filter transfer function. And then the inverse Fourier transform is performed to get the resultant image. Frequency domain image enhancement is used to describe the analysis of mathematical functions and signals with respect to frequency and operate directly on the transform coefficients of the image, such as Fourier transform,

discrete wavelet transform (DWT), and discrete cosine transform (DCT). The advantages of frequency domain are, less computational complexity, manipulating the frequency composition of the image. The disadvantages are, it cannot simultaneously enhance all parts of image in good manner and it is also difficult to automate the image enhancement procedure [11].

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1.1IMAGE ENHANCEMENT TECHNIQUES:-
Histogram Equalization (HE):-

The histogram of an image is a plot of number of occurrences of gray levels in the image against the gray level values. The histogram provides a convenient summary of the intensities in an image. Equalisation is the process that attempts to spread gray level in an image so that they are evenly distributed across their range. Histogram equalization reassigns the brightness values of pixels based on image enhancement. Histogram equalization provides more visually pleasing results [2].

Adaptive Histogram Equalization (AHE) is used for improving contrast in images. It differs from Histogram Equalization by adaptive method that computes several histograms and eachhistogram corresponding to a distinct section of an image. The contrast of region for an image will not be sufficiently enhanced by Histogram Equalization. AHE improves this enhancement by transforming each pixelwithatransformation function derived from a neighborhood region. It is used to overcome some limitations of global linear min- max windowing method. Thus it reduces the amount of noise in regions of the image. And also AHE have the ability forimproving the contrast of grayscale and color image [11].

Dynamic Stochastic Resonance (DSR) [11] an external noise of an image is considered for an image. And the Adaptive DWT based Dynamic Stochastic Resonance uses internal noise for improving performance of an input image. It produces output without artifacts, ringing, blocking of the image. The adding of noise to the input image is useful for non-linear systems using this technique. By using lower noise intensities in SR mechanism the signal cannot be able to reach the threshold value. In this technique the noise allows the signal to reach the threshold value. Thus Adaptive DWT based Dynamic Stochastic Resonance is suitable for enhance both the gray scale and coloured image [11].

Singular value decomposition(SVD) is based on a theorem from linear algebra which says that a rectangular matrix A, which is a product of three matrices that is (i) an orthogonal matrix UA, (ii) a diagonal matrix ΣA and (iii) the transpose of an orthogonal matrix VA. The singular-value-based image equalization (SVE) technique is based on equalizing the singular value matrix obtained by singular value decomposition (SVD). SVD of an image, can be interpreted as a matrix, is written as follows:

$$A = U_A \Sigma_A V_A^T$$

Basic enhancement occurs due to scaling of singular values of the DCT coefficients. The singular value matrix represents the intensity information of input image and any change on the singular values change the intensity of the input image. The main advantage of using SVD for image equalization, ΣA contains the intensity information of the image[2].

1.2 TRANSFORMS FOR IMAGE ENHANCEMENT

Wavelet Transform (WT)

Wavelet transform is capable of providing the time and frequency information simultaneously. The frequency and time information of a signal .But sometimes we cannot know what spectral component exists at any given time instant. The best we can do is to investigate that what spectral components exist at any given interval of time.

Higher frequencies are better resolved in time, and lower frequencies are better resolved in frequency. This means that, a certain high frequency component can be located better in time (with less relative error) than a low frequency component & low frequency component can be located better in frequency compared to high frequency component [8].

Discrete Wavelet Transform (DWT)

The discrete wavelet transform (DWT) is an implementation of the wavelet transform using a discrete set of the wavelet scales for numerical analysis and functional analysis. A time-scale representation of a digital signal is obtained using digital filtering techniques. In the discrete wavelet transform, filters of different cut-off frequencies are used to analyse the signal at different scales. If the wavelets are discretely sampled, the resultant coefficients are called as discrete wavelet transforms (DWT) [8].

The decomposition of images into various frequency ranges permits the isolation of the frequency into certain sub-bands. This process results in isolating small changes in an image mainly in low frequency sub-band images. The 2D wavelet decomposition of an image is performed by applying 1D DWT along the rows of the image first, and, then, the results are decomposed along the columns. This Decomposition results in four decomposed sub-band images referred to as low-low (LL), low-high (LH), high-low (HL), and high-high (HH) [2].

Stationary wavelet transforms (SWT)

SWT is also being used for the image resolution enhancement [3]. SWT is similar DWT but does not use down sampling, hence all the sub-bands will have the same size of the input image[5]. The SWT is an inherently redundant scheme as the output of each level of SWT contains the same number of samples as the input – so for a decomposition of N levels there is a redundancy of N in the wavelet coefficients[3].

Discrete cosine transforms (DCT)

DCT converts a signal from spatial domain into a frequency domain. DCT is real-valued and provides a better approximation of a signal with few coefficients. This approach reduces the size of the normal equations by discarding higher frequency DCT coefficients. Important structural information is present in the low frequency DCT coefficients. Hence, separating the high-frequency DCT coefficient and applying the illumination enhancement in the low–frequency DCT coefficient, it will collect and cover the edge information from satellite images. The enhanced image is reconstructed by using inverse DCT and it will be sharper with good contrast [2].

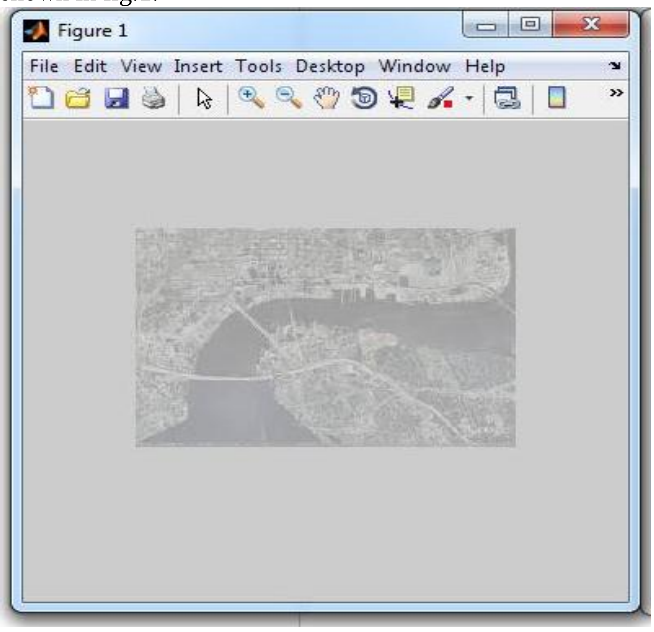
II. PERFORMANCE ANALYSIS

2.1 Algorithm using Directional WT and DCT:

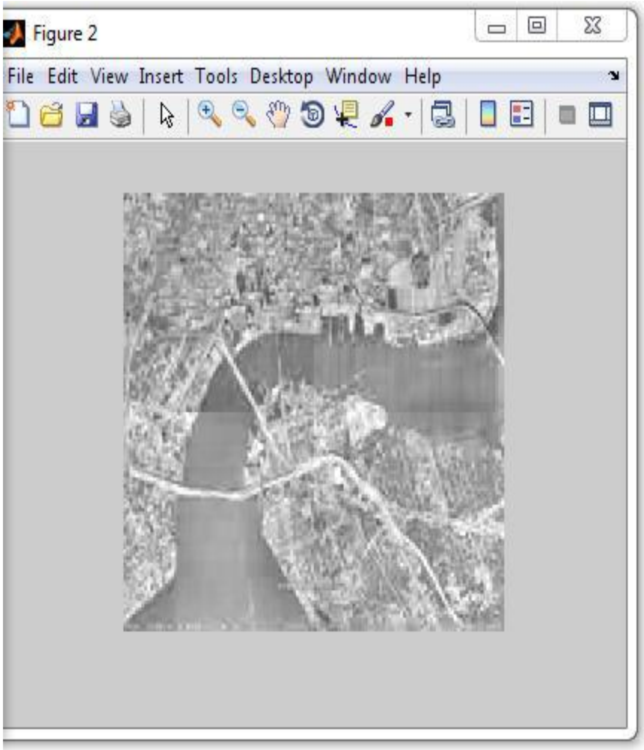
In [1] DWT is a linear transformation that operates on a data vector whose length is an integer power of two, transforming it into a numerically different vector of the same length and DCT exploits interpixel redundancies to render excellent decorrelation for most natural images .

2.2 Algorithm using DWT, DCT & SVD:

In [2] the algorithm used gives better contrast as well as high image quality. The effectiveness of the proposed algorithm is shown in fig.1.



(a)



(b)

Fig.1 (a) Input satellite image (b) Output satellite image [2]

Table.1 shows the comparison between proposed methodology and already existing techniques. In this the Mean for satellite image has decreased but Standard Deviation has increased.

Table.1 Comparison results between proposed methodology and already existing technique [2]

	Mean	Standard Deviation
Input satellite image	179.0545	12.3043
DWT+SVD	157.0131	11.1123
Proposed technique	168.5849	29.1964
Input CT Scan Image	88.2227	88.1706
DWT+SVD	90.5319	90.4389
Proposed technique	94.3802	98.2193

2.3 Algorithm using DWT, SWT & SVD:

In [3] satisfactorily contrast enhancement & super resolution images are obtained from the low resolution images but it losses some information during interpolation. This problem of losing information was overcome in [5]. In [5] along with DWT &SWT, SVD is used which improves the illumination of the image and also protects the edge information. Table 2compares the PSNR values for various techniques for resolution & contrast enhancement . The PSNR value of the proposed technique was found to be 26.01dB for Baboon image.

Table. 2-Comaparision of PSNR (dB) values for various techniques for resolution and contrast enhancement from 128x128 to 512x512

Techniques/images	Lena	Baboon	Peppers
Bilinear	24.83	20.61	25.66
Bicubic	25.84	121.47	25.57
SWT & DWT	26.74	22.01	26.45
Proposed technique	30.63	26.01	28.46

2.4 Undecimated WT based Enhancement Algorithm:

In [4] the proposed algorithm uses the undecimated WT which provides higher visual quality improving the local contrast and resulting in a balanced tonal renedition for the enhancement of colour images. The enhancement results are shown in fig.[4] while the Visual Contrast Measure(VCM) results are given in Table.2.

Fig. 2 VCM result [4]

Table.2 VCM Results [4]

Image	Original	Enhanced
KP01.BMP	37	92
KP03.BMP	27	51
KP05.BMP	83	92
KP06.BMP	37	53
KP07.BMP	50	64

2.5 Algorithm using Dynamic Stochastic Resonance with DWT:

In [6] a dynamic stochastic resonance (DSR) based technique in DWT domain is used for enhancement of very dark greyscale & coloured image. This DSR based technique used inherent noise of a dark image for implementing DSR. Table 3.shows Distribution separation measure (DSM) values attained by DWT based DSR technique and other various contrast enhancement techniques.

Table.3 DSM (and iteration values, n for DSR-based) for DWT- DSR and other existing contrast enhancement techniques [6]

Technique	Metric	Test 1	Test2	Test 3	Test 4	Test 5	Test 6
DWT-DSR	**DSM**	**56.97**	**5.5896**	**144.2**	**51.52**	**11.02**	**84.08**
	n	**50**	**250**	**450**	**400**	**350**	**100**
DFT-DSR	DSM	32.03	4.5758	92.50	8.012	4.463	88.40
	n	8000	8000	8000	8000	8000	8000
HE	DSM	55.77	4.9920	90.85	16.41	7.737	67.36
GC γ=1.5	DSM	45.98	9.04	116.8	24.26	11.61	83.4
SSR	DSM	28.61	3.6846	85.50	12.27	4.413	78.15
MSR	DSM	5.910	0.3910	20.11	6.771	1.156	13.14
MHPF	DSM	21.71	7.2688	63.18	12.83	1.546	56.94

2.6 Algorithm using WT and weighted filter:

In [7] the proposed algorithm uses a weighted filter for enhancing global brightness and contrast of images and WT to enhance the colour information. The flowchart of the proposed method is shown in fig.3.

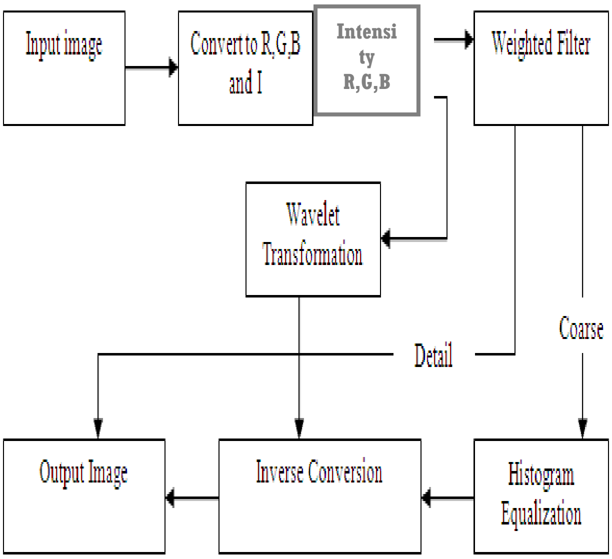
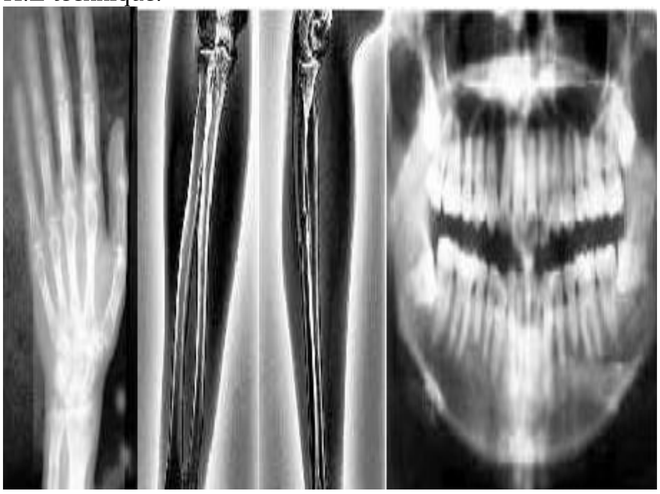


Fig.3. Weighted filter algorithm [7]

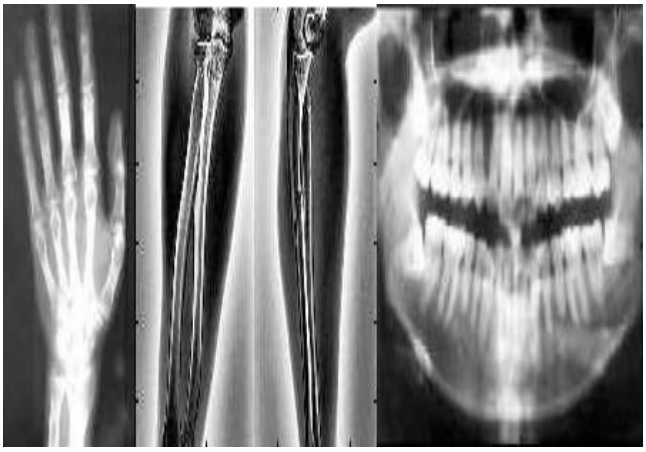
This paper concludes that the proposed method in [7] performs better than the auto-level function in the commercial image-editing software. It not only brightens the darker areas but also preserves the details in highlighted area and removes noise.

2.7 Algorithm using non-linear enhancement technique:

In [8] the non-linear enhancement technique is used to increase the contrast level of an image like WT and Histogram Equalization. In fig 4(a) shows the original image ofhand , legs & teeth while Fig.4(b) shows the results of pre-processed H.E technique.



(a)



(b)

Fig 4(a) Original image (b) Enhanced image with pre-processed histogram equalization

Table 4 shows the comparison of different techniques based on PSNR & MSE values. The results of PSNR are increasing in pre-processed H.E technique and MSE has decreased.

Table 4 Comparisons based on MSE & PSNR [8]

Image (BMPimages)	Techniquename	MSE(ForRecovered Enhancement)	PSNR(dB)(ForRecovered Enhancement)
Hand. Bmp (469x700)	Histogramequalization	5.4342e+003	9.6665
	DWT	3.2720	41.8697
	preprocessedhistogram	8.3631e-005	87.7942
Legs. Bmp (338x278)	Histogramequalization	1.9219e+003	14.1806
	DWT	38.2930	31.1866
	preprocessedhistogram	4.7692e-005	90.2334
Teeth.Bmp (275x183)	Histogramequalization	3.2144e+003	11.9469
	DWT	18.2275	34.4106
	preprocessedhistogram	2.6123e-005	92.8476

2.8 Algorithm using Modern Retinex Technique (MSR & SSR):

Paper [9],[10] concludes that Modern Techniques Retinex (MSR& SSR) performs much better than H.E, Homomorphic Filtering because it is based on colour consistency theory but it still suffers from colour violation & unnatural colour rendition problem which can be improved by applying WT

III. COMPARISON OF WT BASED IMAGE ENHANCEMENT ALGORITHM:-

Comparison of all Wavelet transform based all existing algorithm are discussed here.

S.no	Reference paper	Algorithm	Wavelet used	Measuring parameters	Advantage	Disadvantage
[1]	Image Enhancement using Wavelets	Directional WT+DCT	Mexican Hat Kernel Wavelet	MSE PSNR	Removes interpixel redundancy &improves contrast of an image	Cannot adapt local information of an image.
[2]	Image Enhancement using DWT, DCT & SVD	AHE+DWT +DCT+SVD	1D DWT	Mean(μ)=94.3802 Standard Deviation(σ) =98.2193	Suitable for low contrast satellite& CT scans images enhancement	Used only for greyscale images & not for color images

[3]	Resolution enhancement of images with interpolation& DWT-SWT Wavelet Domain components	DWT+SWT	Daubechies Wavelet	PSNR=26.96dB	Super resolution images are obtained from low resolution images	Losses some information during interpolation
[4]	Undecimated Wavelet transform based contrast enhancement	Undecimated WT based enhancement algorithm	UWT	VCM=92	Provides high visual quality & can be used for both colored and greyscale images.	_
[5]	Image resolution & contrast enhancement using Discrete Wavelet Transform	HE+DWT +SWT+SVD	1-level DWT+ Daubechies 9/7	PSNR=26.01dB SSIM=0.9625	Provides good resolution & good contrast	Problem of losing information in the histogram of the input image.
[6]	Contrast enhancement of dark images using stochastic resonance in wavelet domain	DSR+DWT	Biorthogonal spline wavelet	DSM=56.97	Highly suitable for contrast enhancement of very dark greyscale &colored images Better visual perception, Less computational complexity.	Problem of bleaching of image.
[7]	A new enhancement approach for enhancing images of digital cameras by changing contrast	HE+WT+ weighted filter	WT		Enhance high contrast images effectively & also preserves details& removes noise. This method is fully automatic & requires no measuring parameter.	It introduces several types of image artifacts.
[8]	Advanced image enhancement based on wavelet & histogram equalization for medical images	Preposed HE	DWT	PSNR=90.2334dB MSE=4.76922-005	Not only enhances the image contrast but also preserve original image quality	Used specifically for medical images,
[9], [10]	a) Colour image enhancement technique: A critical review b) Image enhancement techniques: A selected review	Modern techniques Retinex(SSR & MSR)	WT	_	Provides dynamic range compression preserve most of the details	Suffers from Colour violation &Unnatural colour rendition

The above comparison table concludes that the algorithm using Directional wavelet andDCT removesinterpixel redundancy improving contrast of an image but is unable to adapt local information of an image. Algorithm described in [2] is suitable for low contrast satellite and CT scan images but is applicable for only grey scale images. Algorithm used in [3] and [5]provides good resolution and good contrast but losses some information . Undecimated transform based enhancement algorithm provides high visual quality and can be used for both coloured and greyscale images but losses some features. DSR along with DWT algorithm is suitable for very dark greyscale and coloured images with less computational complexity to provide better visual perception, but the only problem is bleaching of image. Algorithm used in [7] enhances high contrast images and also preserves details and removes noise but it still introduces several type of image artifacts.Proposed histogram equalization enhances image contrast preserving original image quality but is specifically used for medical images. Modern technique retinexi.e. SSR and MSR in [9], [10] preserves most of the details but suffers from colour violation and unnatural colour rendition.

IV. CONCLUSION

Literature review concludes that Modern techniques retinex (SSR & MSR) performs much better because it is based on colour consistency theory but it suffers from colour violation and unnatural colour rendition problem. The undecimatedwavelet transform provides high visual quality

improving local contrast and resulting in a balanced tonal rendition for the enhancement of colour images, so in future work there is a scope of applying undecimatedwavlet transform along with retinex to improve image enhancement results such as colour rendition problem, PSNR.

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