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Image Contrast Enhancement using Pyramidal Transforms and SVD

Sreelakshmi S.[1], Anoop K. Johnson[2]

PG Student [SP], Dept. of ECE, Mar Baselios College of Engineering and Technology, Trivandrum, India[1]

Assistant Professor, Dept. of ECE, Mar Baselios College of Engineering and Technology, Trivandrum, India[2]

ABSTRACT: Image Enhancement is the process that improves the quality of the image for a specific application. Its aim is to provide a better transform representation for future automated image processing. It can be done in spatial domain and frequency domain. In frequency domain, low contrast image can be enhanced based on different transforms. Contrast enhancement of an image is used to improve the perceptibility of the object in the scene by enhancing the brightness difference between objects and their backgrounds. Using different Pyramid Transforms along with Singular Value Decomposition (SVD), the performance can be improved. The advantage of using SVD is to change the illumination effect of an image without changing other image information. In this paper, a comparative study of the enhanced image using different types of Pyramid transforms along with SVD and its performance is measured using different parameters.

KEYWORDS: Singular Value Decomposition, Discrete Wavelet Transform, Discrete Cosine Transform, DCT pyramid, Gaussian Pyramid Transform, Laplacian Pyramid Transform, Steerable Pyramid Transform.

I.INTRODUCTION

Image enhancement is basically improving the interpretability of information in images for human viewers and providing better input for other automated image processing techniques. Modifying the attributes of an image to make it more suitable for a given task is the principal objective of image enhancement. During this process, one or more attributes of the image can be modified. The choice of attributes and the way they are modified are specific to a given task. Human visual system and the observer's experience will introduce a great deal of subjectivity into the choice of image enhancement methods. There exist many techniques that can enhance a digital image without spoiling it. The enhancement methods can broadly be divided in to the following two categories:

1. Spatial Domain Methods
2. Frequency Domain Methods

In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier Transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. These enhancement operations are performed in order to modify the image contrast or the distribution of the grey levels. As a consequence the pixel value (intensities) of the output image will be modified according to the transformation function applied on the input values. Image enhancement is applied in every field where images are ought to be understood and analyzed. For example, medical image analysis, analysis of images from satellites etc. Image enhancement simply means, transforming an image f into image g using T. (Where T is the transformation function). The values of pixels in images f and g are denoted by r and s, respectively. As said, the pixel values r and s are related by the expression,

$$s = T(r) \tag{1}$$

Where T is a transformation that maps a pixel value r into a pixel value s. The results of this transformation are mapped into the grey scale range as we are dealing here only with grey scale digital images. So, the results are mapped back into the range [0, L-1], where $L=2^k$, k being the number of bits in the image being considered. So, for instance, for an 8-bit image the range of pixel values will be [0, 255].

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When Discrete Wavelet Transform (DWT) is applied, four subbands are obtained. The illumination information is embedded in the LL sub band. The edges are concentrated in the other sub bands (i.e., LH, HL, and HH). Hence, separating the high-frequency sub bands and applying the illumination enhancement in the LL sub band only will protect the edge information from possible degradation. After reconstructing the final image by using Inverse Discrete Wavelet Transform (IDWT), the resultant image will not only be enhanced with respect to illumination but also will be sharper. In this paper, in order to overcome the disadvantages of DWT along with SVD and DCT pyramid along with SVD and to improve the performance of the system, DWT along with different Pyramid Transforms such as Gaussian Pyramid Transform, Laplacian Pyramid Transform and Steerable Pyramid Transform along with Singular Value Decomposition (SVD) can be used and also to perform a comparative study of the enhanced image using different types of Pyramid transforms.

II.LITERATURE SURVEY

Contrast enhancement is one of the most important issues in image processing. Contrast is created by the difference in luminance reflected from two adjacent surfaces. If the contrast of an image is highly concentrated on a specific range, the information may be lost in those areas which are excessively and uniformly concentrated. The problem is to optimize the contrast of an image in order to represent all the information in the input image. There have been several techniques to overcome this issue such as general histogram equalization (GHE), local histogram equalization (LHE) and Singular Value Equalization (SVE). In many image processing applications, the GHE technique is one of the simplest and most effective primitives for contrast enhancement, which attempts to produce an output histogram that is uniform. One of the disadvantages of GHE is that the information laid on the histogram or probability distribution function (PDF) of the image will be lost. 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, which can be interpreted as a matrix, is written as follows:

$$A=U_A\Sigma_A V_A^T \tag{2}$$

Where U_A and V_A are orthogonal square matrices known as hanger and aligner, respectively, and the Σ_A matrix contains the sorted singular values on its main diagonal. The idea of using SVD for image equalization comes from this fact that Σ_A contains the intensity information of a given image. Singular value decomposition (SVD)-based techniques have been proposed to enhance the low-contrast images without the limitations associated with the HE methods. SVD can be either performed on the pixel domain or on the frequency domain of an image. The singular-value-based image equalization (SVE) technique is based on equalizing the singular value matrix of the image pixels, which contains the intensity information of a given image, obtained by SVD. For the frequency domain, the low-contrast image is decomposed into the discrete wavelet transform (DWT) sub-bands and the singular value matrix of the low-low (LL) sub-band obtained by SVD is updated [1]. This technique is called DWT–SVD reconstructs the enhanced image through the inverse discrete wavelet transform (IDWT). The performance of this technique has been equalized with GHE, LHE and SVE techniques, and the test results show the superior visual quality of DWT–SVD over the others. Furthermore, a technique based on the Discrete Cosine Transform Pyramid and Singular Value Decomposition (DCT pyramid–SVD) was also proposed to enhance the low-contrast satellite images. Although the SVD-based techniques enhance the low contrast images by scaling its singular value matrix, they may fail to produce satisfactory results especially when the scaling factor is close to 1. The proposed technique not only overcomes the shortfalls of the HE methods, which tend to introduce unnecessary visual artifacts such as saturation or contouring, but it also alleviates the weakness of the SVE, DCT–SVD and DWT–SVD methods which have unsatisfactory results especially in mid brightness. The singular value matrix of the equalized lower bands of the DCT pyramid is calculated as the weighted sum of both the singular matrix of the low sub-band image and the singular matrix of its GHE. The enhanced image is then reconstructed by performing DCT pyramid interpolation on the equalized low sub-band image and the reversed L-shape blocks containing high-frequency image details. Hence, the resultant image not only will have a good contrast, it will also be sharper [2][8].

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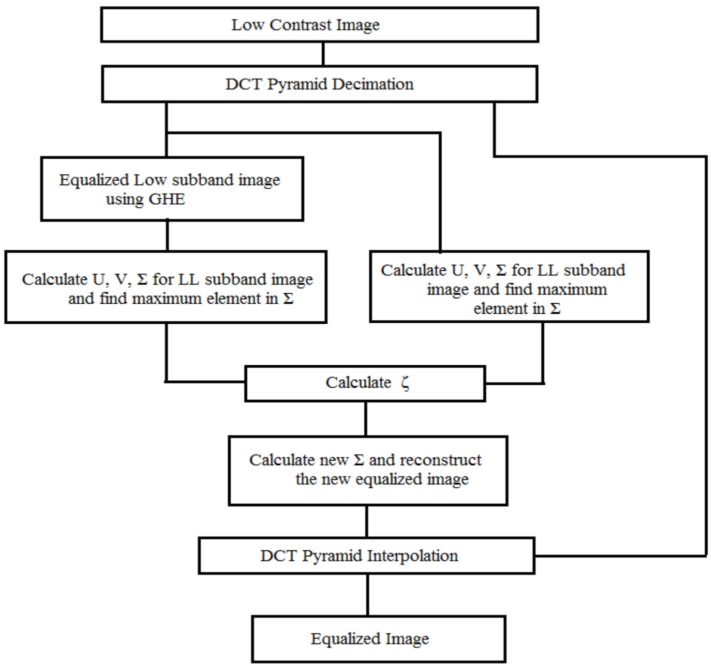

Fig 1: Block diagram for enhancement using DCT pyramid-SVD

SVD has been used for feature extraction, compression and face recognition as well as for the enhancement of the low contrast images. The low-contrast input image *I* is first decomposed with a DCT pyramid into a low sub-band image which contains the illumination information and the reversed L-shape blocks containing the high-frequency coefficients (i.e. edges) of image. The low sub-band image (L_I) is then processed using GHE to generate $\overline{L_I}$. The correction coefficient for the singular value matrix is calculated as

$$\xi = \frac{max(\Sigma_{\overline{L_I}})}{max\ (\Sigma_{L_I})} \qquad (3)$$

The new singular value matrix $\overline{\Sigma_{L_I}}$ of the equalized decimated input image (L_I) is calculated according to the equation

$$\overline{\Sigma_{L_I}} = \alpha\,(\zeta\, \Sigma_{L_I} + (1/\zeta)\, \Sigma_{\overline{L_I}}) \qquad (4)$$

The new equalized low sub-band image $\overline{L_I}$ is given by

$$\overline{L_I} = U_{L_I} \overline{\Sigma_{L_I}} V_{L_I}^T \qquad (5)$$

Finally, through DCT interpolation of $\overline{L_I}$ and the reversed L-shape blocks, an equalized image is produced. The high-frequency coefficients in the reversed L-shape blocks could be scaled up by a certain factor to enhance the edges. It is important to note that despite the similarity in names between DCT and DCT-pyramid, their SVD versions differ significantly. In terms of hierarchical decomposition structure, the DCT pyramid is similar in concept to the DWT whereas the DCT–SVD divides the DCT coefficients into four equally partitioned sets from the lowest to the highest frequency. It should also be mentioned that decomposing an image into a low sub-band and reversed L-shape blocks through a DCT pyramid and performing illumination enhancement in the low sub-band image will protect the edge fidelity from possible degradations. The resultant image will not only be enhanced in terms of illumination but it will also be sharper especially when the coefficients in the reversed L-shape blocks are scaled up [9].

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III.PROPOSED METHODOLOGY

In this paper, Contrast enhancement of images using DWT and different pyramid transforms such as Gaussian Pyramid Transform, Laplacian Pyramid Transform and Steerable Pyramid Transform along with SVD is proposed. The proposed technique overcomes the drawback of DW-SVD, DCT-SVD, and DCT-Pyramid SVD and provides a better enhancement effect. Pyramid or pyramid representation is a type of multi-scale signal representation developed by the computer vision, image processing and signal processing communities, in which a signal or an image is subject to repeated smoothing and sub-sampling. Historically, pyramid representation is a predecessor to scale-space representation and Multi resolution analysis. There are two main types of pyramids; low pass pyramids and band pass pyramids. A low pass pyramid is generated by first smoothing the image with an appropriate smoothing filter and then subs sampling the smoothed image, usually by a factor of two along each coordinate direction. This smoothed image is then subjected to the same processing, resulting in a yet smaller image. As this process proceeds, the result will be a set of gradually more smoothed images, where in addition the spatial sampling density decreases level by level. If illustrated graphically, this multi-scale representation will look like a pyramid, from which the name has been obtained. A band pass pyramid is obtained by forming the difference between adjacent levels in a pyramid, where in addition some kind of interpolation is performed between representations at adjacent levels of resolution, to enable the computation of pixel wise differences [4][5].

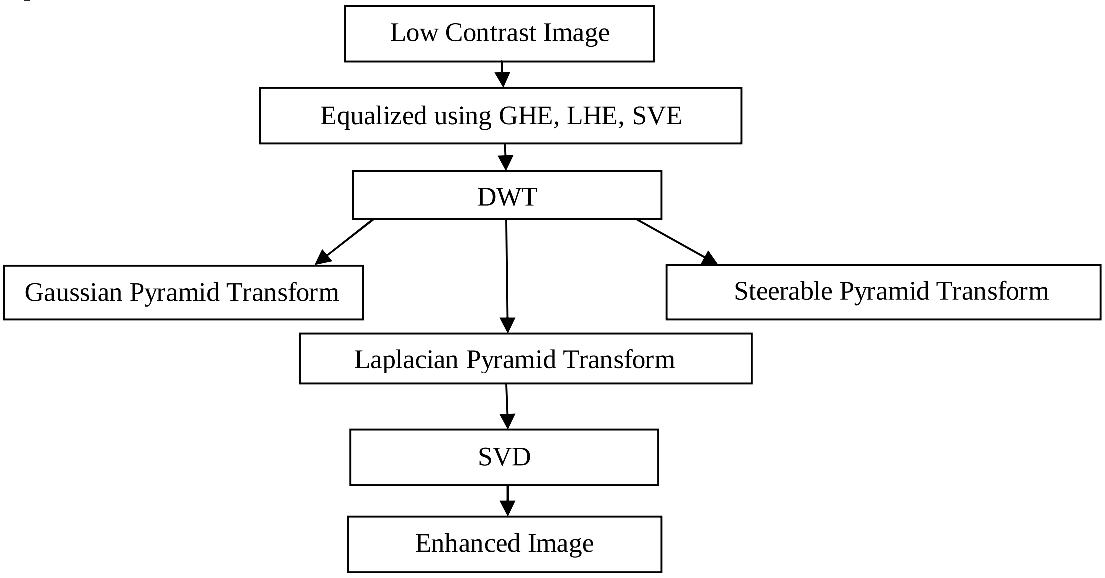

Fig 2: Block diagram for Proposed Method

3.1 Gaussian Pyramid

A Gaussian pyramid is a technique used in image processing, especially in texture synthesis. It is nothing but repeat filtering and sub sampling. The technique involves creating a series of images which are weighted down using a Gaussian average (Gaussians blur) and scaled down. When this technique is used multiple times, it creates a stack of successively smaller images, with each pixel containing a local average that corresponds to a pixel neighbourhood on a lower level of the pyramid. The Gaussian pyramid consists of low-pass filtered, reduced density (i.e., down sampled) images of the preceding level of the pyramid, where the base level is defined as the original image. More formally, let the two dimensional original image be denoted by I(x, y). The Gaussian pyramid is defined recursively as follows:

$$G_0(x,y) = I(x,y), \text{ for level } l = 0$$
$$G_l(x,y) = \sum_{m=-2}^{2}\sum_{n=-2}^{2} w(m.n)\, G_{l-1}(2x+m, 2y+n), \text{ otherwise} \quad (6)$$

Where w(m, n) is a weighting function (identical at all levels) termed the generating kernel which adheres to the following properties: separable, symmetric and each node at level n contributes the same total weight to nodes at level l+1. The weighting function closely approximates the Gaussian function, hence the origins of the pyramids name. Alternatively, the same result can be realized by applying an equivalent weighting function denoted $w_l(m, n)$ (unique

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for each level l) directly to the original image, followed by *l* down sampling operations, where *l* denotes the level number. The equivalent weighting function approximates a Gaussian function that doubles in scale with each level. In the frequency domain the filter's pass band at level *l* is one octave lower than its predecessor level at $l-1$. For an image of dimensions N-by-N the total number of operations (consisting of additions and multiplications) to generate the full pyramid is $7N^2$. An alternative view of the Gaussian pyramid is that each element of the pyramid represents a local average obtained with the equivalent weighting function applied to the original image. Thus the Gaussian pyramid contains local averages at various scales.

Fig 3: First six levels of Gaussian Pyramid

3.2 Laplacian pyramid

A Laplacian pyramid is very similar to Gaussian pyramid with the alteration that it uses a Laplacian transform instead of a Gaussian and is widely used in image processing. It is used to reconstruct an upsampled image from lower image in the pyramid with less resolution. A Laplacian pyramid can be used in Image compression. It computes the difference between upsampled Gaussian pyramid level and Gaussian pyramid level. Laplacian pyramid is used for separating the brightness and contrast components of an image. The brightness component is characterized by slow spatial variations and contrast components tend to vary abruptly. Therefore, the brightness component has low frequency while the contrast component tends to have a relatively high frequency. Each band of Laplacian pyramid is the difference between two adjacent low-pass images of the Gaussian pyramid $[I_0, I_1, ..I_N]$. That is:

$$\overrightarrow{b_k} = \overrightarrow{I_k} - \mathrm{E}\overrightarrow{I_{k+1}} \quad (7)$$

Where $\mathrm{E}\overrightarrow{I_{k+1}}$ is an up-sampled, smoothed version of I_{k+1} (so that it will have the same dimension as I_k)

3.3 Steerable pyramid

The Steerable Pyramid Transform (SPT) was introduced by Freeman and Adelson as an alternative to wavelet transform. It permits to decompose an image into noncorrelated components facilitating thus their analysis and processing. It has been shown that SPT overcomes some drawbacks of DWT. It is a linear multi-scale, multi-orientation image decomposition that provides a useful front-end for image-processing and computer vision applications. This is developed in order to overcome the limitations of orthogonal separable wavelet decompositions that were then becoming popular for image processing (specifically, those representations are heavily aliased, and do not represent oblique orientations well). Once the orthogonality constraint is dropped, it makes sense to completely reconsider the filter design problem. Indeed, the SPT is a multiscale and multidirectional representation that is translation invariant. Furthermore, this representation could be designed in order to make it rotation-invariant. Also, SPT has some advantages of orthonormal wavelet transform (e.g. basis function are localized in space and spatial frequency, the transform is a tight frame) but suffers less from its drawbacks, such as aliasing effects. Another interesting property of the SPT is its polar-separability which is well defined in the Fourier domain. Unlike the DWT, the SPT is overcomplete by the factor $4k/3$. Overcomplete means the number of pixels in the pyramid is greater than the number of pixels in the input image. Therefore it is more adapted to image analysis and processing than to image compression. This elegant transformation has been applied in many applications and especially for image quality enhancement.

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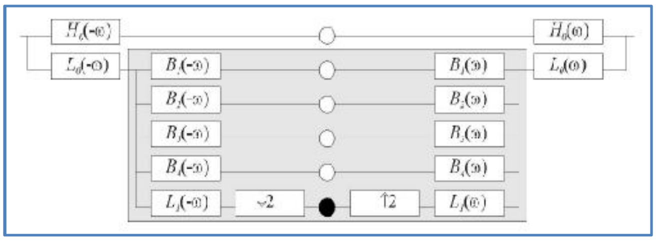

Fig 4: First level of Steerable Pyramid Decomposition

The image shown above is the first level of Steerable Pyramid decomposition. The original image is decomposed into high pass subband and low pass subband using filters H_0 and L_0. The low pass subband is again decomposed in to bandpass subband and a lower level low pass subband. This lower level low pass subband is sampled by a factor 2. Repeating the shaded area provides recursive structure.

IV.PERFORMANCE EVALUATION

The quantitative performance can be obtained by analyzing the estimated Gaussian distribution of the enhanced images which are modeled by using the calculated mean (μ) and standard deviation (σ) of the output images.

The EME is an indication of an average contrast in an image and is known as the measure of enhancement. This measure is obtained by dividing an image I into k1 k2 non-overlapping blocks of size L×L, which was chosen 8 × 8 in this paper, finding the minimum $I_{min;k,l}$ and maximum $I_{max;k,l}$ intensity values in each block and averaging them. It is defined as

$$\text{EME} = \frac{1}{k1\,k2} \sum_{l=1}^{k2} \sum_{k=1}^{k1} 20 \log I_{max;\,k,l} / I_{min;\,k,l} \quad (8)$$

V. RESULT AND DISCUSSION

The performance of the proposed equalization technique was contrasted against the other five methods of GHE, LHE, SVE, DWT–SVD and DCT Pyramid–SVD.

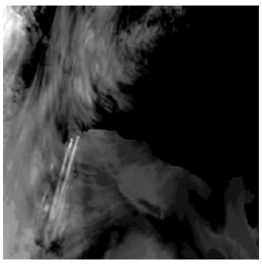

Fig 5a: Original Image

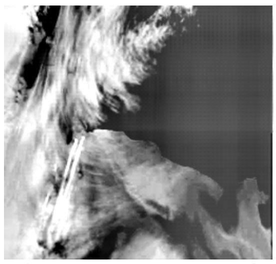

Fig 5b: DWT Gaussian Pyramid SVD

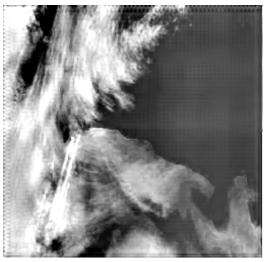

Fig 5c: DWT Steerable Pyramid SVD

Fig 5d: DWT Laplacian Pyramid SVD

The Fig 5a represents a low contrast satellite image, this low contrast image is enhanced using different pyramid transforms such as Gaussian, Laplacian and Steerable pyramid along with SVD is shown in , 5b, 5c, 5d respectively.

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The visual result indicates that the enhancement using DWT Pyramid Transforms along with SVD shows better result compared to DCT Pyramid SVD, DWT-SVD and DCT-SVD. Enhancement is not about its mean it's with respect to standard deviation that is how widely the pdf is distributed i.e., high standard deviation indicates that the data points are spread out over a large range of values. From the above images, good result is obtained while using DWT Gaussian Pyramid Transform rather than DWT Laplacian Transform and DWT Steerable Transform. The quantitative analysis is shown in Table I, represents that there is a slight variation in the EME values between DWT Steerable Pyramid SVD and DWT Gaussian Pyramid SVD, since visually Gaussian pyramid shows better results. Therefore it is concluded that Gaussian Pyramid is better compared to others. The quantitative analysis is shown in Table I.

TABLE I: RESULTS

	Mean(μ)	Std. Deviation(σ)	EME (%)
Original Image	49.4430	3.2831	-
DWT Steerable Pyramid and SVD	127.9502	11.6454	12.7414
DWT Laplacian Pyramid and SVD	128.0008	10.5045	11.7032
DWT Gaussian pyramid and SVD	129.8296	10.6751	12.0234

Fig 6a: Original Image

Fig 6b: DWT Gaussian Pyramid SVD

Fig 6c: DWT Laplacian Pyramid SVD

Fig 6d: DWT Steerable Pyramid SVD

From the above result Fig 6a shows the original image, this is enhanced using different pyramid transforms such as DWT Gaussian Pyramid, DWT Laplacian Pyramid and DWT Steerable Pyramid along with SVD is shown in Fig 6b, 6c, 6d respectively. By using an inbuilt image, visually as well as quantitatively DWT Gaussian Pyramid SVD provides better result compared to other methods. Also Table II gives the quantitative analysis of the result obtained by using the above result.

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TABLE II: RESULTS

	Mean(μ)	Std. Deviation(σ)	EME (%)
Original Image	118.7245	10.2228	-
DWT Steerable Pyramid and SVD	132.4810	13.3616	14.9820
DWT Laplacian Pyramid and SVD	128.1713	14.1451	16.1001
DWT Gaussian pyramid and SVD	128.9331	12.9135	19.1337

VI.CONCLUSION

In this paper, Contrast enhancement of images using different Pyramid Transforms along with Singular Value Decomposition is explained. The result obtained by using an inbuilt image, from the visual result it is clear that DWT Gaussian Pyramid-SVD provide better result compared to other pyramid transforms, DWT-SVD and DCT pyramid-SVD. And also while using a satellite image, obtained visual result indicates DWT Gaussian pyramid have higher contrast enhancement, while considering the quantitative analysis steerable pyramid shows better measure of enhancement. But visually DWT Gaussian Pyramid SVD provide better contrast enhancement. Thus it is concluded that contrast of an image can be enhanced using DWT-Gaussian Pyramid-SVD, which provides better enhancement compared to other methods. The future work can be based on Contourlet transforms along with SVD for further enhancing the contrast.

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