International Journal of Electronics Communication and Computer Engineering
Volume 7, Issue 2, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

Image Contrast Enhancement Using Fast Discrete Curvelet Transform via Unequally Spaced Fast Fourier Transform (FDCT-USFFT)

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***Abstract* – The digital cameras provided a great service for users of different ages as it facilitated the process of capturing the images, and in spite of that user still needs to improve some of the images marred by the lack of clarity when taking an image because of the lack of proper lighting as it is in cloudy weather or bright or dark sites light , or take the image from a distance, leading to blurred image details. We Propose in this paper a new method for contrast enhancement gray images based on Fast Discrete Curvelet Transform via Unequally Spaced Fast Fourier Transform (FDCT-USFFT). This type of transforms returns a table of curvelet coefficients indexed by a scale parameters, an orientation, and a spatial location. The FDCT-USFFT coefficients can be modified in order to enhancement contrast in an image. Results show that the proposed technique gave very good results, in comparison to the histogram equalization and wavelet transform based contrast enhancement method.**

***Keywords* – FDCTs, FDCT-USFFTs.**

I. Introduction

Image enhancement operations consisting of a sets of techniques that trying to enhance the visible appearance of an image or to convert the image to a form more appropriate for analysis by a machine or human[4]. The enhancement expresses accentuation or sharpening of image features, such as contrast, edges, etc [1]. The useful information that can be derived by researchers in digital image processing by the case of image capture in a cloudy atmosphere or opaque site, this causes a problem known as low contrast. Which presents a bad distribution of the lighting situation in the vicinity of the image details. Low contrast is an important problem facing researchers working on gray images, or medical radiography images dark , or images of old documents. The main aim of this paper is the contrast enhancement gray images that have low contrast using FDCT-USFFT to make the images look brighter.

The spatial domain is a direct manipulation of pixels in an image, where works by combining the pixel values of the two or more images of enhanced in a way linear or nonlinear [2,3]. The frequency domain is a manipulation of the orthogonal transform of the image rather than the image itself, where works by 2-D discrete Fourier transform of the image, modify the coefficients transform, and then performing the inverse transform, enhanced in a way low pass or high pass [2,3].

The wavelet based contrast enhancement is a representative of frequency-based enhancement methods. Compared with spatial enhancement techniques, wavelet based contrast enhancement can better remove noise while effectively enhancing contrast and edges [9].

The curvelet transform it has been prepared as an answer to the weakness of the separable wavelet transform in representing curves and edges. It has achieved an important success in a wide set of image processing applications including noise reduction, enhance image etc. So, curvelet transform better than wavelet transform in represent multiscale edge [9].

Accordingly in this paper, the second generation curvelet transform which is concept easier, faster than the first generation is used for enhance gray images. The rest of the paper is organized as follows. Section II review of previous studies. Section III talk briefly about FDCT and FDCT-USFFT. Section IV description about proposed technique. Section V evaluate the frame work and the results show of working with different standard. Section VI description about conclusion and future.

II. Previous Studies

Represents talk about enhancement contrast on the digital images a wide area of interests across specialists and researchers in this area, having dealt with many studies to enhancement contrast research, study and evaluation, the following are some previous studies :

In [5] Y. Juyi : Proposed an enter principle of the second generation Curvelet transform. The tests of colour images show that the algorithm can provide good enhance effect, increase the contrast, reduce noise. It is superior to wavelet and Ridgelet algorithms in both visual effect and performance indicators.

In [6] X. Wang, et, al : Proposes a novel method for enhancing the low contrast of fingerprint images based on fast discrete curvelet transforms, uses nonlinear function based on a row means quantization transform to adjust the coefficient of low frequency sub-band in low frequency component, and uses noise reduction threshold to enhancement the details of the image in high frequency component.

In [8] C. Tao, et, al: Proposes an enhancement algorithm based on FDCT, uses positive transform on input image, means decompose the image into coarse scales and minute scales coefficients, and then make use of a directional filter and a soft threshold function to enhancement image and

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denoising respectively, and implement inverse transform, and reconstruct the enhanced image.

In [13] H. Ahmed, et, al: Proposes a new algorithm fingerprint image enhancement by performing threshold on FDCT domain and applying Gabor Filters. The algorithm reduce noise image of fingerprints by using threshold FDCT, then apply Gabor filters to enhancement the clarity of the image.

In [7] S. Palanikumar, et, al : Proposes a novel approach for enhancing palprint image based on curvelet transform . The enhancement uses to modify contrast of image and denoising. Histogram equalization enhance contrast of image.

In [9] H. Li, et, al: Proposes a novel X-ray image contrast enhancement method using the second generation curvelet transform in order to better enhance contrast and edges while remove noise. Decompose images source in the curvelet transform domain. Combining with threshold a noise reduction, the nonlinear enhancement operator is also applied to high frequency sub-bands to enhance edges and reduce noise. Then, the processed coefficients are constructed to obtain enhanced images.

In [10] C. Ying, et, al : Proposes a technique new image enhancement based on the traditional technology, of between it Curvelet transform which are based on the ridge of the development of the theory of wave, is a kind of new way about the image enhancement technology, Some revisions and attempts were made on the basis of discrete Curvelet transform algorithm, and also coefficient of curevelet transform was revised.

In [11] A. Ein-shoka, et, al: Proposes a method is employing homomorphic filtering in the fast discrete curvelet transform. It was based on mix the advantages of fast discrete curvelet transform for representing curves and clarifying features on it with homomorphic filtering which is an efficient way for enhance of IR images.

In [12] M. Kalyan, et, al: Proposes a new method to enhance the satellite image which using the concept of curve lets and multi structure decomposition. FDCT technology is used to enhancement the image of decomposing input in different sub-bands. Multiple decomposition structure is a powerful theoretical tool, which is used in the analysis of non-linear images. Revealing of the positions edges through decomposition threshold and sharpening these edges by using morphological filters.

After reviewing the scientific research it turns out that most research enhance contrast, edges and noise reduction in medical images and x-rays and some other satellite images and fingerprint images and infrared images. It was observed that it was neglecting enhance image gray. For enhancement contrast or quality in gray images, several techniques has been developed of enhancement contrast but in this paper we propose a new method to enhancement contrast of gray images.

III. Fast Discrete Curvelet Transform (FDCT)

The curvelet transform has two major generations. First generation use a complex steps which include the ridgelet transform of radon transform of an image. Second generation ignores the use of ridgelet transform, the repetition reduced which leads to increased speed [11]. The following is a brief introduction of the Fast Discrete Curvelet transform.

A. Digital Curvelet Transform

These digital transformations are linear and take as input Cartesian arrays of the form $f[t_1,t_2], 0 \le t_1, t_2 < n$, which allows us to think of the output as a collection of coefficients $c^D(j,l,k)$ obtained by the digital analogue [9,14].

$$c^D(j,l,k) = \sum_{0 \le t_1, t_2 < n} f[t_1,t_2] \overline{\varphi^D_{j,l,k}[t_1,t_2]} \qquad (1)$$

where each $\varphi^D_{j,l,k}$ is a digital curvelet waveform.

In figure 1 clarification the basic digital tiling where the windows $\tilde{U}_{j,l}$ Smooth resettlement of Fourier transform near wedges sheared obedience sizing equivalent. The shaded area represents one of these typical wedge [9,14].

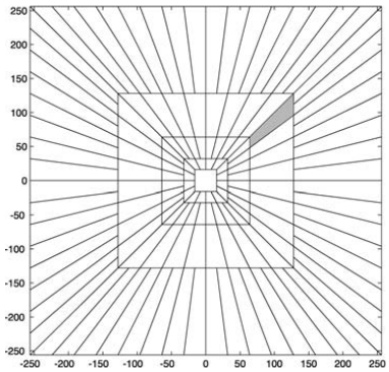

Fig. 1. The figure illustrates the basic digital tiling

The window I_j smoothly extracts frequencies near the dyadic corona and near the angle. Coronae and rotations, as in the continuous-time definition, are not especially adapted to Cartesian arrays, so it is convenient to replace these concepts by Cartesian equivalents; here, "Cartesian coronae" based on concentric squares and shears [9,14].

Now the Cartesian window $\tilde{U}_j$ is defined as:

$$\tilde{U}_j(w) := \tilde{W}_j(w) V_j(w) \qquad (2)$$

Where:

$$\begin{cases} \tilde{W}_j(w) = \sqrt{\Phi^2_{j+1}(w) - \Phi^2_j(w)} \\ V_j(w) = V(2^{\lfloor j/2 \rfloor} w_2 / w_1) \end{cases}$$

The Φ is defined as the outcome of low-pass 1D windows:

$$\Phi_j(w_1, w_2) = \phi(2^{-j} w_1)\phi(2^{-j} w_2)$$

Obviously it $\tilde{U}_j$ insulates frequencies near the wedge, is an equivalent Cartesian to the window [14]. Displays now the group of equispaced cliffs tan and define

$$\tilde{U}_{j,l}(w) := \tilde{W}_j(w) \tilde{V}_j(S_{\theta l} w) \qquad (3)$$

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The S_θ is the shear matrix:

$$S_\theta = \begin{pmatrix} 1 & 0 \\ -\tan\theta & 1 \end{pmatrix}$$

B. FDCT-USFFTs

In what follows, we choose to work with the windows as in (1). Hence, the discrete curvelet coefficients are defined as [14]:

$$c(j,l,k) = \int \hat{f}(w)\tilde{U}_j(S_{\theta l}^{-1} w)e^{i\langle S_{\theta l}^{-T} b, w\rangle}\, dw \qquad (4)$$

where b takes on the discrete values $b := (k_1 . 2^{-j}, k_2 . 2^{-j/2})$.

Asks us to evaluate inverse discrete Fourier transform on the non-standard sheared network $S_{\theta_l}^{-T}(k_1 . 2^{-j}, k_2 . 2^{-j/2})$ and, regrettably, it does not apply to FFT algorithm classic [14]. To restore the convenient rectangular network, can pass the shearing operation to $\hat{f}$ and rewrite (4) as

$$c(j,l,k) = \int \hat{f}(w)\tilde{U}_j(S_{\theta l}^{-1} w)e^{i\langle b, S_{\theta l}^{-T} w\rangle}\, dw = \int \hat{f}(S_{\theta_l} w)\tilde{U}_j(w)e^{i\langle b, w\rangle}\, dw.$$

From the interpolating trigonometric polynomial, also denoted $\hat{f}$, and defined by

$$\hat{f}(w_1, w_2) = \sum_{0 \le t_1, t_2 < n} f[t_1, t_2]e^{-i(w_1 t_1 + w_2 t_2)/n} \qquad (5)$$

With these notations, the FDCT via USFFT simply evaluates

$$c^D(j,l,k) = \sum_{n_1, n_2 \in P_j} \hat{f}[n_1, n_2 - n_1 \tan\theta_l]\tilde{U}_j[n_1, n_2]e^{i2\pi(k_1 n_1/L_{1,j} + k_2 n_2/L_{2,j})}$$

where $P_j = \{(n_1, n_2) : n_{1,0} \le n_1 < n_{1,0} - L_{1,j}, n_{2,0} \le n_2 < n_{2,0} + L_{2,j}\}$, and $(n_{1,0}, n_{2,0})$ is the index of the pixel at the bottom-left of the rectangle. Because of the parabolic scaling, $L_{1,j}$ is about 2^j and $L_{2,j}$ is about $2^{j/2}$.

In USFFT based on the translation network is tilted to be aligned with the orientation of the curvelet, resulting individualize most loyal of the continuous definition. There is a network taking different samples for each collection scale/orientation. For a certain range, this corresponds to only two networks sampling Cartesian, one for all angles quarters in the east and the west and one to the north and south quadrants [14].

IV. Proposed Technique

The proposed technique, has the capability to enhance the contrast in digital images in efficient manner by using the FDCT-USFFT based contrast enhancement algorithm. Ago the FDCT -USFFT is well-adapted to represent images containing edges, it is a good candidate for edge enhancement. the FDCT -USFFT coefficients can be modified in order to enhance edges in an image. A function y_c must be defined which modifies the values of the FDCT -USFFT coefficients. We introduce explicitly the noise standard deviation σ in the equation [15]

$$y_c(x,\sigma) = 1 \qquad if\ x < c\sigma$$

$$y_c(x,\sigma) = \frac{x - c\sigma}{c\sigma}\left(\frac{m}{c\sigma}\right)^p + \frac{2c\sigma - x}{c\sigma} \qquad if\ x < 2c\sigma$$

$$y_c(x,\sigma) = \left(\frac{m}{x}\right)^p \qquad if\ 2c\sigma \le x < m$$

$$y_c(x,\sigma) = 1 \qquad if\ x \ge m$$

Where p determines the degree of nonlinearity. c becomes a normalization parameter, and a c value larger than 3 guaranties that the noise will not be amplified. The m parameter is the value under which coefficients are amplified. This value depends obviously on the pixel values inside the FDCT-USFFT scale. Therefore, we found it necessary to derive the m value from the data [15].

- m can be derived from the noise standard deviation $(m = k_m\sigma)$ using an additional parameter k_m = 15. The advantage is that k_m is now independent of the curvelet coefficient values, and therefore much easier for a user to set. For instance, using m = 30, c = 3 and p = 0.5.

The FDCT-USFFT enhancement method for grayscale images consists of the following step:

Step 1:

Input image *I*.

Step 2 :

Calculate the FDCT -USFFT of the input image. We get a set of bands w_j, each band w_j contains N_j coefficients and corresponds to a given resolution level .

Step 3

Calculate the noise standard deviation σ_j for each band j of the FDCT-USFFT.

Step 4:

For each band j do Multiply each FDCT-USFFT coefficient $w_{j,k}$ by $y_c(|w_{j,k}|, \sigma_j)$.

Step 5:

Reconstruct the enhanced image from the modified FDCT-USFFT coefficients.

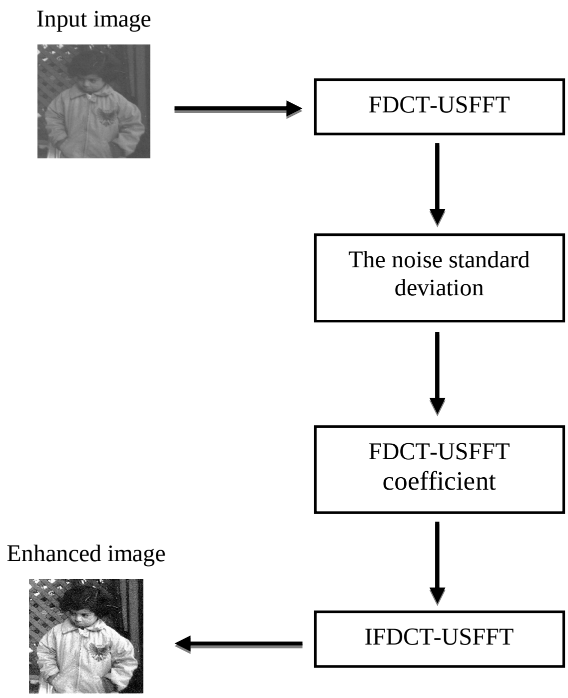

Fig. 2. Diagram proposed technique

V. Results Evaluation

In the tests, the proposed technique has been implemented to set of low contrast gray images of 512×512 size . The technique has been implemented in MATLAB, using the curve-lab toolbox to get the Fast Discrete curvelet coefficients using unequal Spaced Fast Fourier transform. We have compared the proposed technique with the

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histogram equalization and wavelet transform based contrast enhancement.

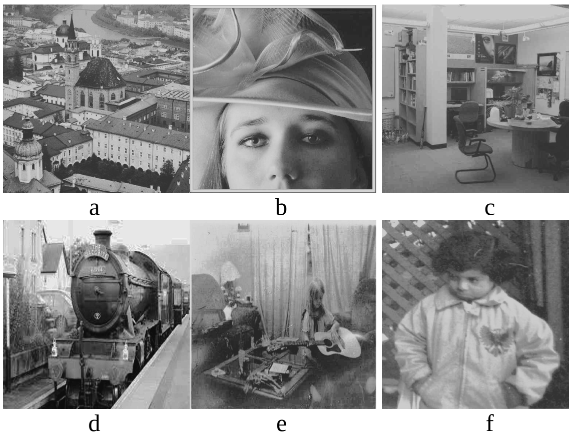

Fig. 3. Images after applying Wavelet Transform

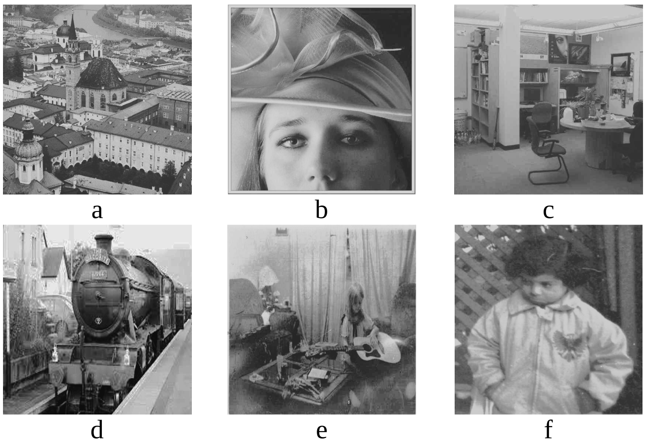

Fig. 4. Images after applying Histogram Equalization

Fig. 5. Images after applying Wavelet Transform

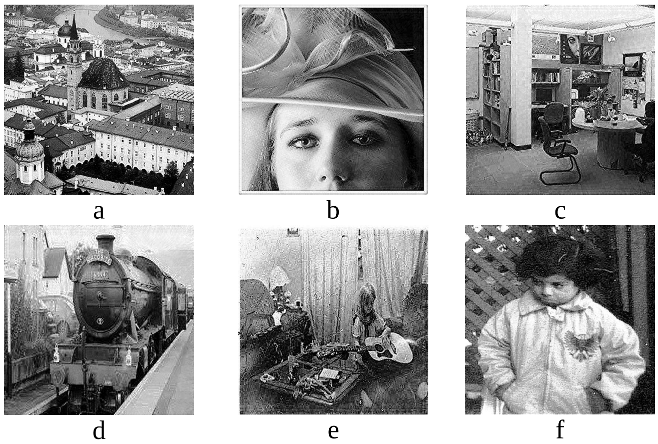

Fig. 6. Images after applying Proposed Technique

Furthermore, we saw the output images from the contrast enhancement operations. Also, the results were compared with the original image using visual tests. Some performance measures showed that the proposed method gives better results.

A. Measure of Entropy (ME)

ME is a statistical measure of randomness is used to describe the texture of an image. The entropy is accounted using Shannon's entropy theory. Whenever the entropy is high it is clear that a high-contrast image [16]. If p means the histogram count of an image, entropy can be defined as;

$$ME = \sum_{i=1}^{m}\sum_{j=1}^{n} P(i,j)\log 2(P(i,j))$$

Table 1 showed the comparison among proposed and the histogram equalization and wavelet transform based on Measure of Entropy.

Table 1. Analysis Measure of Entropy

Image	Histogram Equalization	Wavelet Transform	Proposed Technique
a	5.5635	6.3571	6.8333
b	5.8923	6.5304	6.8845
c	5.5515	5.2822	5.9226
d	5.83	6.9509	7.3094
e	5.3755	5.7354	5.7921
f	5.7997	5.5491	6.3651

B. Structural Similarity Index (SSIM)

The Structural Similarity (SSIM) Index quality assessment index is based on the computation of three terms, namely the luminance term, the contrast term and the structural term. The SSIM index is calculated on various windows of an image [17]. The measure between two windows x and y of common size N×N is:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

where $\mu_x, \mu_y, \sigma_x, \sigma_y$ and σ_{xy} are the local means, standard deviations, and cross-covariance for images x, y; $C_1 = (k_1L)^2$, $C_2 = (k_2L)^2$ two variables to stabilize the division with weak denominator; *L* the dynamic range of the pixel-values. The resultant SSIM index is a decimal value

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between -1 and 1, and value 1 is only reachable in the case of two identical sets of data [16].

Table 2 showed the comparison among proposed and the histogram equalization and wavelet transform based on Structural Similarity Index.

Table 2. Analysis Structural Similarity Index

Image	Histogram Equalization	Wavelet Transform	Proposed Technique
a	0.56487	0.82251	0.92036
b	0.71442	0.9098	0.93051
c	0.57616	0.89859	0.96065
d	0.7803	0.90468	0.91065
e	0.51627	0.88932	0.94854
f	0.63092	0.89175	0.90668

C. Peak Enhanced to Original Image Ratio (PEOIR)

Two commonly used objective measures to check the quality of image are Mean Squared Difference (MSD) and Peak Enhanced to Original Image Ratio (PEOIR) defined as [25]

$$MSD = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(I_e - I_0)^2$$

$$\text{PEOIR} = 10 \log_{10} (\text{Imax}^2/\text{MSD})$$

Where *Imax* is the maximum intensity of enhanced image I_e is the enhanced image and I_o is original image intensity. In order to get a high quality contrast enhanced image, the intensity difference between both enhanced and original image must be very high. Hence the quality of processed image will be higher for high values of MSD, which means that there is a large difference between the intensities of enhanced and original image. Therefore PEOIR will be small for high values of MSD.

Table 3 showed the comparison among proposed and the histogram equalization and wavelet transform based on Peak Enhanced to Original Image Ratio.

Table 3. Analysis Peak Enhanced to Original Image Ratio

Image	Histogram Equalization	Wavelet Transform	Proposed Technique
a	30.7424	25.1099	24.7547
b	35.8019	32.3760	30.7184
c	36.0816	34.6523	31.0105
d	32.3144	30.5065	28.4056
e	35.762	27.5433	24.3144
f	31.5622	29.0654	26.5333

VI. Conclusion and Future

There are various techniques used in enhance images according to the image type. A technique that is used to enhance a certain type of images may not give the best results for another type. This is as a result of the different quality standard for each image. We propose an efficient method to enhance low contrast in gray image. Results show that the proposed technique is computationally efficient, with the same level of the contrast enhancement performance. Noise neglected in this paper. The technique new is better than histogram equalization and wavelet transform in image quality. Further work includes:

1. Color Image Contrast Enhancement Using 3D Fast Discrete Curvelet Transform.
2. Pseudo out product based fuzzy neural network will be used to image contrast enhancement.

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