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Image Contrast Enhancement Using Fast Discrete Curvelet Transform via Wrapping (FDCT-Wrap)

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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 Wrapping (FDCT-Wrap). This type of transforms returns a table of curvelet coefficients indexed by a scale parameters, an orientation, and a spatial location. The FDCT-Warp 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-Wrap, Contrast Enhancement.

I. Introduction

The images are the most common and convenient to transfer or information transfer. An image is worth a thousand words. Images convey brief information about the positions, sizes and mutual relations between the objects [19-66].
Image enhancement operations consists of the 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 [2]. The enhancement expresses accentuation or sharpening of image features, such as contrast, edges, etc [3]. In contrast refers to the difference in lighting or gray level values in an image and is a key attribute. Contrast ratio has a strong impact on the image [1].
Image enhancement paths are divided into two parts spatial domain methods and frequency domain methods. 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. The frequency domain is the manipulation of orthogonal transforming the image instead 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 [4,5].
Transform is converting the image from spatial to a frequency domain. The inverse transform is converted image from frequency to spatial domain. Transforms – Gray values are represented in a different domain, but equivalent form, for example, Fourier, wavelet[4,5].
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 [6].
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 [18].
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 2 reviews of previous studies. Section 3 talks briefly about FDCT and FDCT-Wrap. Section 4 presents description about proposed technique. Section 5 evaluates the frame work and the results show of working with different standard. Section 6 gives 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 [1] M. Kalyan, et, al: Proposes a new method to enhance the satellite image which using the concept of curvelets and multi structure decomposition. Fast Discrete Curvelet Transform technology is used to enhancement the image of decomposing input in different sub-bands. Multiple decomposition structures 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.
In [6] 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 the 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 [7] Y. Juyi: Proposed an enter principle of the second generation Curvelet transform. The tests of color images show that the algorithm can provide good enhance the effect, increase the contrast, reduce noise. It is superior to wavelet and Ridgelet algorithms in both visual effect and performance indicators.
In [8] 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 subband in low-frequency component, and uses noise reduction threshold to enhancement the details of the image in high-frequency component.
In [9] S. Palanikumar, et, al: Proposes a novel approach for enhancing palmprint image based on curvelet transform. The enhancement uses to modify contrast of an image and reduce noise. Histogram equalization enhances the contrast of an image.
In [10] C. Tao, et, al: Proposes an enhancement algorithm based on fast discrete curvelet transform, 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 enhance image and reduce noise respectively, and implement inverse transform, and reconstruct the enhanced image.
In [11] 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 of the image enhancement technology, Some revisions and attempts were made on the basis of discrete Curvelet transform algorithm, and also, coefficient of curvelet transform was revised.
In [12] A. Ein-shoka, et, al: Proposes a method is employing homomorphic filtering in the fast discrete curvelet transform. It was based on the 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 enhancing of IR images.
In [13] H. Ahmed, et, al: Proposes a new algorithm fingerprint image enhancement by performing threshold on fast discrete curvelet transform domain and applying Gabor Filters. The algorithm reduces noise image of fingerprints by using threshold Fast Discrete Curvelet Transform, then apply Gabor filters to enhancement the clarity of the image.
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 [10,14].

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

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 [10,14].

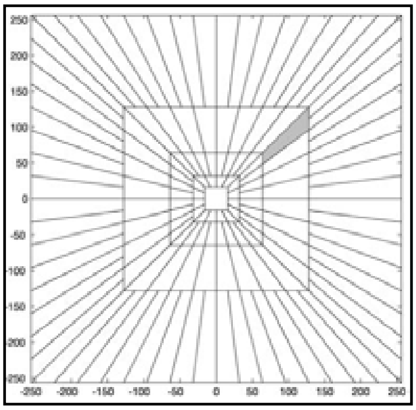

Fig.1: The figure illustrates the basic digital tiling

The window U_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 [10,14].

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

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

Where:

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

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

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

The S_θ is the shear matrix:

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

B. FDCT-Wrap

Supposedly a wrapping approach the same digital coronization as in paragraph (1) but makes it different, the choice somewhat easier than the spatial network to translate curvelets in every scale and angle. Instead of a tilted network, we assume a regular rectangular network and determine Cartesian curvelets in basically the same way as before, [14]

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

After individualization, and embedded during the ω an amount becomes n_1, n_2 that would exceed allowed by the 2D IFFT. The Similarity (11) with the standard 2D IFFT in this regard only formal. To understand why respect for the sizes of the rectangle is a concern, we recall that the $\tilde{U}_{j,l}$ is supported in a parallel region [14].

$P_{j,l} = S_{\theta_l} P_j$

For most the variable angular values $\theta_l, P_{j,l}$ it supports inside the rectangle $R_{j,l}$ in line with the axes of lengths and with ribs both on the order of 2^j .

The wrapped windowed data, about the origin, then it is defined as restricting of $Wd[n_1, n_2]$ to indicators n_1, n_2 inside a rectangle with sides of length $L_{1,j} \times L_{2,j}$ near the origin:

$0 \le n_1 < L_{1,j}, \qquad 0 \le n_2 < L_{2,j}$

Correspondence between the original and wrapped indicators is a one-to-one. It is possible to express the wrap of the array $d[n_1, n_2]$ about the origin of more simply by using the modulo function:

$$Wd[n_1 \bmod L_{1,j}, n_2 \bmod L_{2,j}] = d[n_1, n_2], \qquad (5)$$

with $(n_1, n_2) \in P_{j,l}$.

In wrapping the network is the same in every corner in every quadrant—yet all curvelet gave proper orientation. As well, instead of interpolation, periodization is used to localize Fourier samples in the rectangular area where IFFT can be applied [14].

4 The Proposed Technique

The proposed technique has the capability to enhance the contrast in digital images in efficient manner by using the FDCT-Warp based contrast enhancement algorithm. Ago the FDCT - Warp is well-adapted to represent images containing edges, it is a good candidate for edge enhancement. The FDCT - Warp 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 - Warp 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- Warp 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 FDCT- Warp coefficient values, and therefore much easier for a user to set. For instance, using $m = 30$, $c = 3$ and $p = 0.5$.

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

step 1:
Input image I.

step 2 :
Calculate the FDCT - Warp 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- Warp.

step 4:
For each band j do Multiply each FDCT- Warp coefficient $w_{j,k}$ by $y_c(|w_{j,k}|, \sigma_j)$.

step 5:
Reconstruct the enhanced image from the modified FDCT- Warp coefficients.

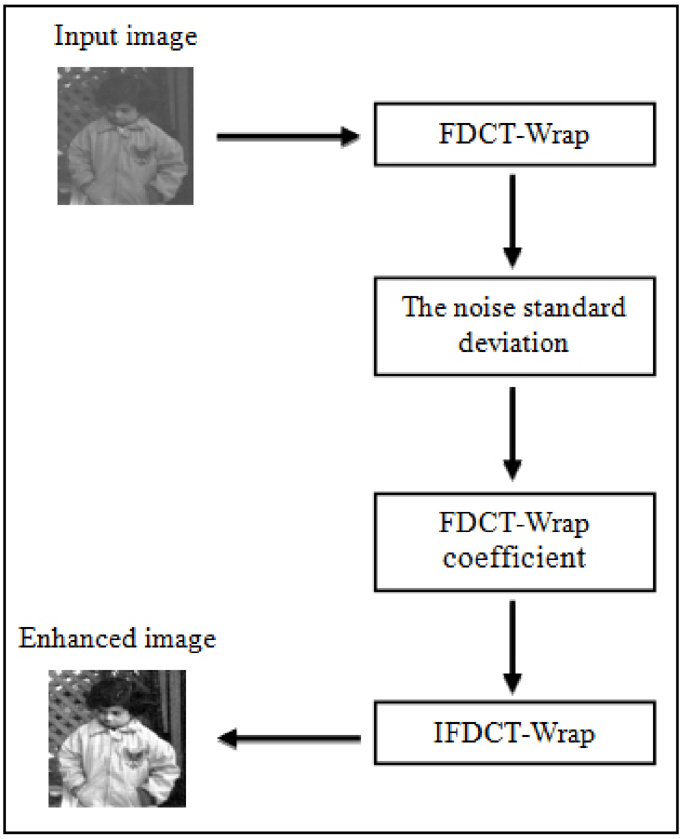

Fig. 2: Block Diagram of the proposed technique

IV. 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 Wrapping. We have compared the proposed technique with the histogram equalization and wavelet transform based contrast enhancement.

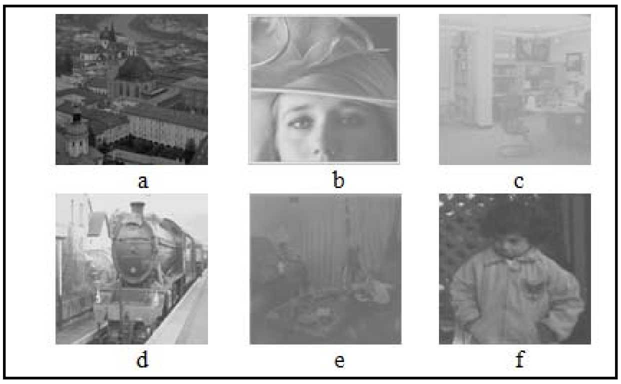

Fig. 3: Input images of 512×512 size namely (a-f) low contrast images

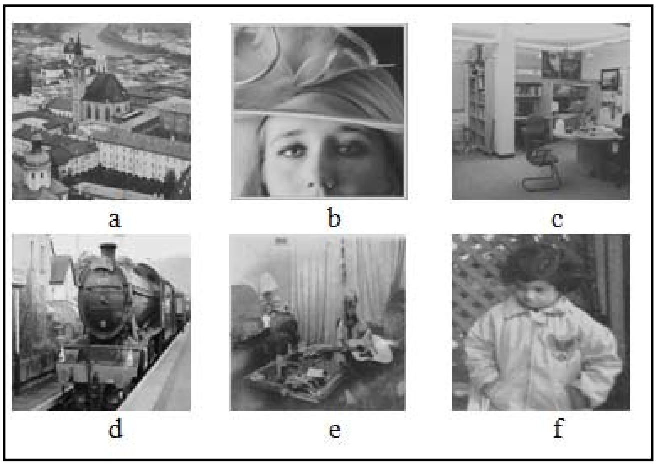

Fig. 4: Images after applying Wavelet Transform

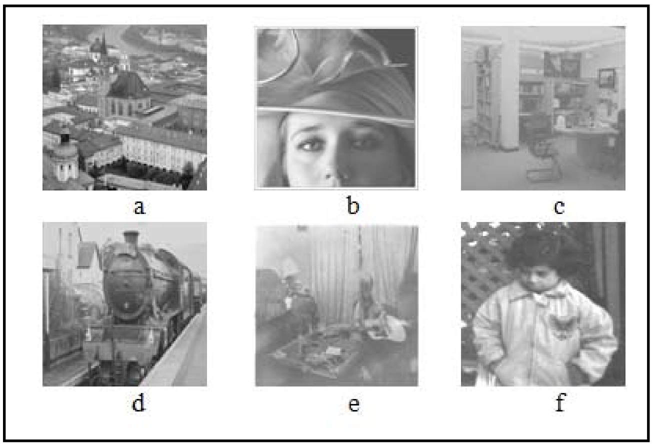

Fig. 5: Images after applying Histogram Equalization

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;

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

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

Table1: Analysis Measure of Entropy

Image	Histogram Equalization	Wavelet Transform	Proposed Technique
a	5.5635	6.3571	6. 8709
b	5.8923	6.5304	6. 8937
c	5.5515	5.2822	5. 9761
d	5.83	6.9509	7. 3526
e	5.3755	5.7354	5. 8494
f	5.7997	5.5491	6. 41

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 μ_x , μ_y , σ_x , σ_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 between 0 and 1, and value 1 is only reachable in the case of two identical sets of data [17]. We compare the enhancement between original image and enhanced image.

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	0.93546
b	0.71442	0.9098	0.94792
c	0.57616	0.89859	0.96983
d	0.7803	0.90468	0.92541
e	0.51627	0.88932	0.94988
f	0.63092	0.89175	0.93003

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 [16]

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

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

Where *Imax* is the maximum intensity of enhanced image I_e is the enhanced image and I_o is low contrast 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[16].

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	24.7033
b	35.8019	32.3760	29.7092
c	36.0816	34.6523	30.8913
d	32.3144	30.5065	27.2825
e	35.762	27.5433	23.3526
f	31.5622	29.0654	24.5427

V. Conclusion and Future work

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 proposed technique 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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