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Enhancement of IR Images using Homomorphic Filtering in Fast Discrete Curvelet Transform (FDCT)

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ABSTRACT
This paper presents an efficient model for enhancement of Infrared images. The proposed method is employing homomorphic filtering in the Fast Discrete Curvelet Transform (FDCT). It based on mixing the advantages of FDCT for representing curves and clarifying features on it with Homomorphic filtering which is an efficient method for enhancing the appearance of IR images. Also, we investigate the influence of FDCT coefficients on the Infrared images. The proposed method gives good results with respect to objective and subjective measurements when using only the first and last FDCT coefficients.

General Terms
Infrared images Enhancement.

Keywords
Image Enhancement, Homomorphic Filtering, FDCT

1. INTRODUCTION
Recently Infrared (IR) Images attract the attention of most researchers due to their importance in many areas like medical, military, night vision. IR images have a lot of advantages (high sensitivity, low price, high security, low power requirements), however there are some disadvantages (low PSNR, Resolution, contrast, and difficulty to detect objects), also IR images have large black areas and small details due to the absence of light needed for imaging. These problems limit the overall performance of IR images. So, it is necessary to enhance the original IR images[1][2].

Image Enhancement means processing an image so that the result is more suitable than the original image for a specific application, and to improve images for human vision. In this paper, we propose a n efficient model for enhancement based on combining homomorphic filtering and Fast Discrete Curvelet Transform (FDCT)[3].

The following sections of paper show the detailed of homomorphic filtering and Fast Discrete Curvelet Transform (FDCT). Then the proposed model is introduced, and evaluation methods for measurements metrics are explained. Finally, results and conclusion are presented.

2. HOMOMORPHIC FILTERING
Homomorphic filter is used for image enhancement .An image is characterized by two main components:

1. Illumination is the amount of source light incident on the scene being viewed and denoted as $I(x, y)$.
2. Reflectance is the amount of light reflected by the objects in the scene and denoted as $R(x, y)$ [3][4].

Since an image $F(x, y)$ can be expressed as[4]:

$$F(x, y) = R(x, y).I(x, y) \quad 1$$

To implement homomorphic function we do the following step:

1. Apply the natural logarithm to the image to change multiplication operation into addition [5].

$$p(x, y) = \ln[F(x, y)] = \ln[I(x, y)] + \ln[R(x, y)] \quad 2$$

$$FFT\{\ln(f(x, y))\} = FFT\{\ln(I(x, y))\} + FFT\{\ln(R(x, y))\} \quad 3$$

2. Transform the image into frequency domain [4].

Or

$$F_p(u, v) = F_i(u, v) + F_r(u, v) \quad 4$$

3. High pass the by a mean of a filter function in frequency domain [6].

$$z(u, v) = F_p(u, v)H(u, v) = F_i(u, v)H(u, v) + F_r(u, v)H(u, v) \quad 5$$

4. Take an inverse Fourier transform to get the filtered image in the spatial domain [4].

$$z(x, y) = IFFT\{z(u, v)\} = IFFT\{F_i(u, v)H(u, v)\} + IFFT\{F_r(u, v)H(u, v)\} \quad 6$$

5. Finally, the desired enhanced image can be obtained by the exponential operation [4]:

$$F'(x, y) = e^{z(x,y)} \quad 7$$

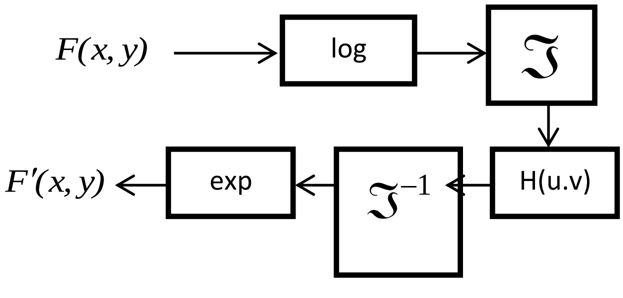

Fig 1: Homomorphic Filtering

3. FAST DISCRETE CURVELET TRANSFORM (FDCT)

Curvelet is a two multiscale geometric transforms. In many applications, images exhibit edges and discontinuities across curves. The edge preservation is important in obtaining details of the input image [7]. Curvelet is better for edge representation. The Curvelet has two major generations. The first generation used a complex steps involving the ridgelet analysis of radon transform of an image. The performance was slow [7][8]. This generation based on unequally-spaced FFT. The second generation neglects the use of ridgelet transform, the redundancy reduced and thus the speed is increased. This generation based on wrapping of specially selected Fourier samples. In the proposed the wrapping version is used of the curvelet transform [7]. The wrapping coefficients can be calculated using the fnollowing equation [9]:

$$C(j, l, k)=\int \hat{f}(w) U_{j,\theta_l} e^{ib,w} dw \qquad 8$$

Where, c(j, l, k) is FDCT coefficients, U_{j,θ_l} represent the real-valued wedge window.

4. PROPOSED MODEL

The proposed model depends on the following steps:

1- The FDCT frequency wrapping is applied to the IR image to obtain the curvelet coefficients given by Eq. 8.
2- Apply homomorphic filtering to FDCT coefficients for IR image.
3- The final enhanced IR image is reconstructed by applying Inverse Fast Discrete Curvelet Transform (IFDCT) on the enhanced coefficients.

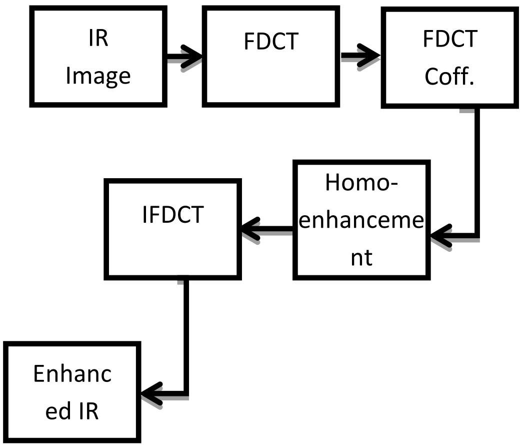

Fig 2: the proposed model

5. EVALUATION METRICS

Image quality is very important in many fields of image processing such as image enhancement. it help us in knowing the adequacy of enhanced images for use in any of the different areas and applications. There are two types to measure image quality one of them is human eye vision but this method is not enough, so we turned to the mathematical measurements .there are many of these measurements, some of these techniques are used to measure quality of the IR image enhancement. They are:

5.1 Local contrast

It is an index for the image quality and purity of view. and one of the most important measurement for Infrared images ,due to the difficulty of distinguishing objects from their background, local contrast important to identify objects and also in the trace. It can be calculated from this equation [10]:

$$c_{local} = \frac{|\mu_{target} - \mu_{background}|}{\mu_{target} + \mu_{background}} \qquad 9$$

5.2 Average Gradient

Average gradient is a way to measure the resolution and contrast of the images, it refer to the clarity of details in the image. If the average gradient is high the resolution of the image will be higher also which mean that the image is enhanced further [10].

$$avg = \frac{1}{(M-1)(N-1)} \sum_{i=1}^{(M-1)(n-1)} \sqrt{\frac{(\frac{\partial f}{\partial x})^2 + (\frac{\partial f}{\partial y})^2}{2}} \qquad 10$$

5.3 Standard Deviation

Standard deviation STD shows how far from the mean value. STD can be obtained from this equation [10]:

$$STD = (\frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} (f(i,j) - \mu)^2)^{1/2} \qquad 11$$

5.4 Edge Intensity

Image Edge detection is a way of evaluating the quality of image, one of the methods used in image edge detection is the Sobel operator. In this method, two filters h_x and h_y is used. And they can be expressed as [10] :

$$h_x = \begin{pmatrix} 1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix}, \ h_y = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \qquad 12$$

In case of an image *P*, the Sobel edge intensity (S) can be obtained by combining the results of the last two mentioned convolution processes as following [10]:

$$s_x = f * w_x \ , s_y = f * w_y \qquad 13$$

$$s = \sqrt{(s_x^2 + s_y^2)} \qquad 14$$

5.5 PEAK SIGNAL TO NOISE RATIO

It is a quantitative measure based on the RMSE (root mean square error) [10].

$$PSNR = 10 \times \log (\frac{(f_{max})^2}{RMSE^2}) \qquad 15$$

6. RESULTS

The proposed model imposes two cases, the first case applying the proposed on only two coefficients of the FDCT they are C1 {1, 1} {1, 1} and C2 {1, 4} {1, 1}, the first and last coefficients. The resulted image is enhanced as shown from the table results. The second case applying the proposed on all FDCT coefficients, the resulted image has a better view and results. The two cases are presented below. (We used an IR image of size 128 x 128).

6.1 Case 1

(a)

(b)

(c)

Fig 3 : results of case 1, (a) is the original image, (b) enhanced image using two FDCT coefficients, (c) enhanced image using all coefficients.

Table 1. results of case 1 using, (a) represent original image, (b) proposed using two FDCT coefficients, (c) proposed using all coefficients..

Metrics / Algorithm	(a)	(b)	(c)
Average gradient	8.241	7.659	7.921
Standard deviation	46.351	58.599	45.625
Edge intensity	79.268	72.127	76.075
Local contrast	0.4772	0.4865	0.4987
PSNR	41.0607		40.3422
Time (second)	0.9196		4.096

6.2 Case 2

(a) (b)

(c)

Fig 4 : results of case 2, (a) is the original image, (b) enhanced image using two FDCT coefficients, (c) enhanced image using all coefficients.

Table 2. results of case 2 using, (a) represent original image, (b) proposed using two FDCT coefficients, (c) proposed using all coefficients

Metrics / algorithm	(a)	(b)	(c)
Average gradient	9.157	8.174	9.8129
Standard deviation	37.978	47.325	43.207
Edge intensity	98.325	87.031	104.85
Local contrast	0.537	0.537	0.632
PSNR	46.997		41.926
Time(second)	1.758		6.434

7. CONCLUSION

This paper proposes an efficient algorithm for IR image enhancement. In this algorithm homomorphic filtering is mixed with FDCT transform in two different stages. In the first stage only two coefficients of the FDCT were used. In the second all the coefficients of the FDCT were used. According to the results in the last tables, using the whole coefficients is better in the term of quality measures but it takes more time. With respect to the two coefficients which takes less time but lower enhancement efficiency. From this results the proposed with two coefficient can be used in application that is time sensitivity like military, medical. However an application such as temperature forecasting time is not effect greatly. So, the proposed with all coefficients can be used. For future work the proposed can be applied on neural and genetics and determine the enhancement results.

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