Image Contrast Enhancement using Discrete Dual Hahn Moments

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Abstract

The main objective of this paper is to develop a simple technique for contrast enhancement of monochrome and color images using Discrete Dual Hahn (DDH) moments. The basic idea of our approach is to measure a local contrast at each band of a DDH moment matrix and use it to modify them. These modified moments are used to construct the enhanced image by taking the inverse DDH moment transform. For color images only luminance image was enhanced using the above procedure. Hence, other components are not changed. We compute image entropy, coefficient of information content and universal quality index for verifying the results with alpha rooting, Kratchouk moment and Tchebichef moment based approaches.

1. Introduction

The Principal objective of Image enhancement is to process a given image so that the result is more suitable than the original image for a specific application. One normally apply contrast enhancement technique on those images that are captured in poor illuminating conditions or captured with a sensor having nonlinear gain or captured in non uniform illuminating conditions, Some of the areas where these techniques are useful are in digital photography, medical image analysis, remote sensing, LCD display processing and scientific visualization. Several image enhancement techniques were proposed during the last few years and they are grouped into two categories: Spatial domain and Transform domain techniques. Some of the well known spatial domain techniques are Histogram Equalization[2], Gray level Grouping [5,6] etc. Transform domain techniques modify the transform coefficients obtained either using Wavelet transform or Fourier transform or Discrete Cosine transform or Hadamard [18] or Hartly transform [18]. Some of the known techniques are alpha rooting and contrast enhancement using DCT[1,8], Hadamard and Hartly transforms. In recent years both discrete and continuous orthogonal moments such as Geometric, Legendre, Zernike, Tchebichef, Hahn, Kracthouk and Gaussian Hermite moments were applied for solving image watermarking, Human Gait recognition, content base image retrieval, Texture classification [7], Finger Print classification [11], License Plate character recognition [12], stereo matching [9], moving object recognition [10] and SAR image segmentation [13] problems. In this paper Discrete Dual Hahn moments are chosen for image enhancement because a) no discretization errors like in continuous moments. b) more flexibility in describing the image because they use more parameters in their definition. c) Other discrete moments like Tchebichef and Kratchouk moments can be obtained from these moments. Further the size of the moment matrix is less than the image size. Therefore image can be reconstructed with lesser number of moments.

This paper is organized into 5 sections. Second section presents details on Discrete Dual Hahn moments. Contrast Enhancement using DDH moment coefficients is presented in section 3. Simulation results are given in section 4. Finally, conclusions and extensions are reported in section 5.

2. Discrete Dual Hahn Moments

Dual Hahn moments are defined based on the weighted dual Hahn polynomials. These polynomials are orthogonal on a non uniform lattice, but the discrete dual Hahn moments defined in this paper can still be applied for uniform pixel grid by introducing an intermediate, non uniform lattice [3]. Given a uniform pixel lattices image f(s,t) with size NxN, the (n+m)th order dual Hahn moment is defined as

$$G_{nm} = \sum_{s=a}^{b-1} \sum_{t=a}^{b-1} w_n^c(s,a,b) w_m^c(t,a,b) f(s,t) \quad \ldots(1)$$

$$n, m = 0,1 \ldots N-1$$

In the above expression $w_n^c(s,a,b)$ denote the weighted dual Hahn polynomials and variables s and t represents horizontal and vertical directions of the reconstructed image with uniform pixel grid. Parameters a, b and c are restricted to

$$-\frac{1}{2} \prec a \prec b \ |c| \prec 1+a, b = a+N$$

Inverse moment transform given below can be used for reconstructing the image

$$f(s,t) = \sum_{a=0}^{N-1} \sum_{b=0}^{N-1} G_{nm} w_n^c(s,a,b) w_m^c(t,a,b)$$

$$s,t = a, a+1, \ldots\ldots\ldots b-1$$

If only the DDH moments of order up to M are used then N is replaced by M in the above expression. Weighted Dual Hahn polynomials are obtained by the following recursive equation

$$w_n^c(s,a,b) = A\frac{d_{n-1}}{d_n}w_{n-1}^c(s,a,b) + B\frac{d_{n-2}}{d_n}w_{n-2}^c(s,a,b)$$

Where

$$a_0 = s(s+1)$$

$$a_1 = (b-a-c-1)$$

$$A = \frac{1}{n}[a_0 - a_b + a_c - b_c - a_1 * (2n-1) + 2(n-1)^2$$

$$B = -\frac{1}{2}(a+c+n-1)(b-a-n+1)(b-c-n+1)$$

with

$$w_0^c(s,a,b) = \sqrt{\frac{\rho(s)}{d_0^2}}(2s+1)$$

$$m_0 = \sqrt{\frac{\rho(s)}{d_1^2}}(2s+1)$$

$$w_1^c(s,a,b) = -\frac{1}{\rho(s)}\frac{\rho_1(s)-\rho_1(s-1)}{x(s+\frac{1}{2})-(x-\frac{1}{2})} * m_0$$

$$\frac{d_{n-1}^2}{d_n^2} = \frac{n}{(a+c+n)(b-a-n)(b-c-n)}$$

$$m_1 = (a+c+n), m_2 = (a+c+n-1)$$

$$m_3 = (b-a-n+1), m_4 = (b-a-n)$$

$$m_5 = (b-c-n+1), m_6 = (b-c-n)$$

$$\frac{d_{n-2}^2}{d_n^2} = \frac{(n-1)}{m_1 * m_2 * m_3 * m_4 * m_5 * m_6}$$

Weight function $\rho(s)$ and norm d_n^2 is given by

$$\rho(s) = \frac{\Gamma(a+s+1)\Gamma(c+s+1)}{\Gamma(s-a+1)\Gamma(b-s)\Gamma(b+s+1)\Gamma(s-c+1)}$$

$$d_n^2 = \frac{\Gamma(a+c+n+1)}{n!(b-a-n-1)\Gamma(b-c-n)}$$

$$n = 0,1\ldots(N-1)$$

$$\rho_n(s) = \frac{\Gamma(a+s+n+1)\Gamma(c+s+n+1)}{\Gamma(s-a+1)\Gamma(b-s-n)\Gamma(b+s+1)\Gamma(s-c+1)}$$

Figure 1 displays the reconstructed image using the DDH moments with parameters a=0, b=256 and c=0.In the above equations we need a factorial of 256 when the image size 256 x256 is used. This can be solved by simplifying the above equation before they are used in the implementation.

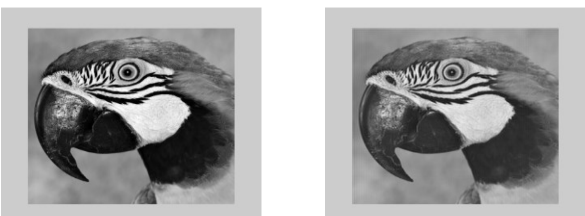


Figure 1. a) Original image b) Reconstructed image

3. Contrast Enhancement Using DDHM

Discrete Dual Hahn Moment coefficient matrix of size 128x128, obtained using the equation (1) is divided into 255 different frequency bands as shown in Figure 2. Local contrast at n[th] frequency band [1] (n ≥ 1) is defined as

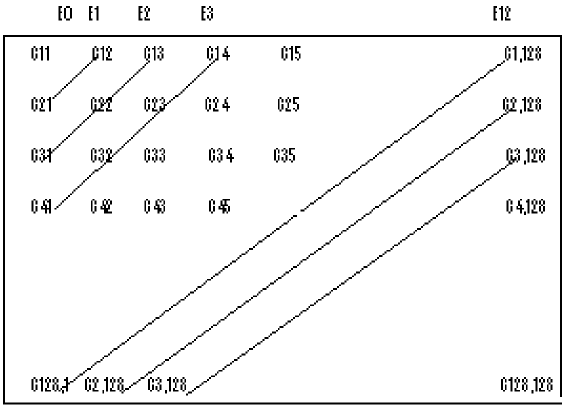


Figure. 2. Diagram Showing Different Frequency Bands

$$C_n = \frac{E_n}{\sum_{t=0}^{n-1} E_t} \quad \text{Where } E_t = \frac{\sum_{p+q=t}|G_{p,q}|}{N}$$

is the average of the coefficient magnitudes in each band. N is the number of elements at each band and it is given by

$$N = \begin{cases} t+1 & t \prec 128 \\ 254 - t + 1 & t \geq 128 \end{cases}$$

It can be shown [1] that the Enhanced Discrete Dual Hahn moment coefficients $\overline{G}_{p,q}$ as

$$\overline{G}_{p,q} = \lambda H_{p+q} G_{p,q} \qquad p+q \geq 1,$$

$$\text{Where } H_n = \frac{\sum_{t=0}^{n-1} \overline{E}_t}{\sum_{t=0}^{n-1} E_t} \qquad n \geq 1$$

$$\overline{E}_n = \lambda H_n E_n \quad n \geq 1$$

H_n (n=1,2,……254) can be obtained by recursion. In this expression λ is an image enhancement control factor if λ >1, the image will be enhanced and for 0 < λ < 1 image will be softened.

3.1 Alpha Rooting Technique

In this approach the magnitude of each DDHM coefficient is raised to a power α. Let Gp,q be the DDHM coefficients of the original image and modified DDHM coefficient $\tilde{G}_{p,q}$ is given by $\tilde{G}_{p,q} = G_{p,q}\left|\frac{G_{pq}}{\max(G)}\right|^{\alpha-1}$

Figures 5 and 7 shows the enhanced monochrome and color images using the above approach for α=0.98 value. The image obtained using the above approach is darker than the other approaches and this point can be noticed in the histogram shown in figure 8.

4. Simulation Results

Proposed approach was applied for both monochrome couple and color girl images. Results are shown in Figures 4 to 7. For color images only luminance image was enhanced. In order to verify the quality of the obtained images, image entropy [14], Coefficient Information Content [14] and Universal Quality Index[15] was calculated for both original and enhanced images and the results are reported in Table 1, first value is for monochrome image and second value is for color image and they are separated by symbol dash. In all our simulation results λ=1.25 was used for both monochrome and color images, but λ =0.98 was used for Tchebichef moment based approach. From the values reported in Table 1 and figures 8 and 9 one can say that moment based approaches retains full details and visual quality of the enhanced images are good. We have also tested the proposed approach for increasing value of λ and observed that the image appeared more brighter than the original image. For small values of λ the details are moderately enhanced. Histograms of the Enhanced images shown in figures 8 and 9 are smooth and wider than the original image. In figure 9 only luminance image histogram is shown because the proposed approach was applied to this image only. Enhanced image using the DDHM is better than the other methods.

Figure 3. Original Monochrome and color Images

5. Conclusions

In this paper DDHM are used for image contrast enhancement for both monochrome and color images. We observed that visual quality of the enhanced image is better than the other methods. One can still improve the results by replacing the λ value by a function of the spatial frequency [16]. In order to enhance the time varying images we need temporal DDH moments [10].

Figure 4.Enhanced Image using DDHM and Kratchouk moments

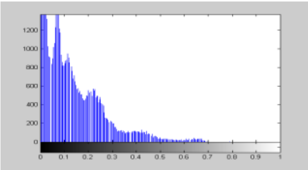
Figure 5. Enhanced image Tchebichef moments and Alpha Rooting method

Figure 6.Enhanced image using DDH and Kratchouk moments

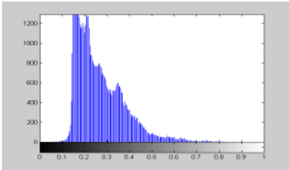
Figure 7. Enhanced image using Tchebichef moments and Alpha Rooting method

TABLE I. PERFORMANCE EVALUATION OF ENHANCEMENT TECHNIQUES

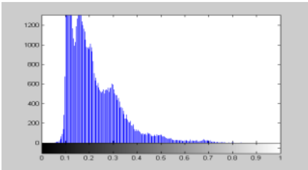
Method	Entropy	Co-Info-Content	UIQ Index
Original Image	3.190-3.35	63.19-51.41	1-1
Dual Hahn Moments	3.85-3.55	187.81-122	0.66-0.63
Kratchouk Moments	3.67-3.7	135.6-95.4	0.64-0.77
Tchebichef Moments	3.198-3.12	32.16-32.08	0.548-0.99
Alpha rooting (DDHM)	3.16-3.34	33.9-39.72	0.88-0.99



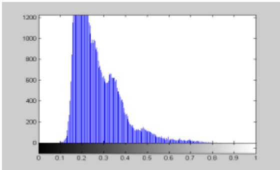
a) Original



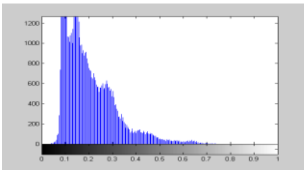
b) DD Hahn



c) Kratchouk

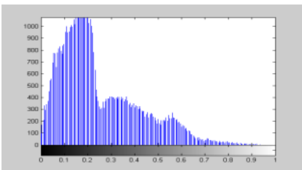


d) Tchebichef

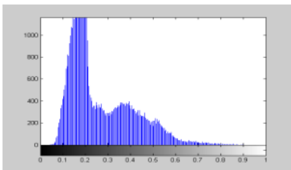


e) Alpha Rooting

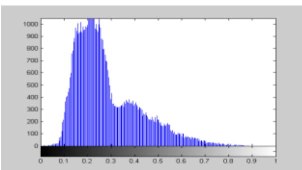
Figure 8. Histograms of images shown in Fig 3, 4 and 5



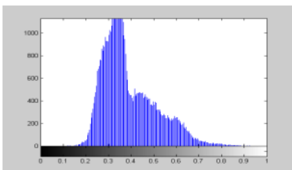
a) color image



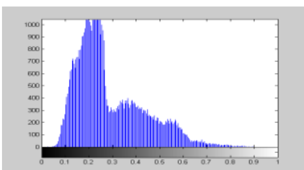
b) DD Hahn



c) Kratchouk



d) Tchebichef



e) Alpha rooting

Figure 9. Histograms of images shown in Fig 3, 6 and 7

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