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Global and Local Contrast Enhancement of Digital Imagery using Discrete Wavelet Transform

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***Abstract*— Processing of contrast enhancement of an image is the vital role in digital image processing. A better contrast enhancement method provides better visual features than the original image. This paper aims at achieving the visual artifacts - free image using the process of contrast enhancement. The proposed method involves Spatial-Entropy based Contrast Enhancement (SECE) to enhance the global features in an image. This algorithm is combined with transform domain (2D discrete wavelet transform (2D-DWT)) to achieve global and local enhancement simultaneously. Then coefficient weighting is performed followed by Inverse Discrete Wavelet Transform (IDWT) to obtain globally and locally enhanced image. The 2D-DWT overcomes the drawbacks of 2D-DCT by removing visual artifacts and processing the image in sub-bands effectively with proper parameter selection. Thus the proposed method outperforms than other contrast enhancement techniques.**

Keywords—Contrast Enhancement, Spatial Entropy, Discrete Cosine Transform, Discrete Wavelet Transform

I. INTRODUCTION

Some features present in digital images cannot be easily detected by human eye. They can be made visible by increasing the contrast of an image with low brightness or to bring out image details that would otherwise be hidden. It is achieved by increasing the difference between the object and background and it is generally employed as a preprocessing for majority of image processing and in other computer vision algorithms. In general, it is difficult to design a visual artifact free contrast enhancement method. In order to achieve such enhancement, an efficient contrast enhancement technique has been developed which is based on spatial location of gray-levels of an image. The mutual information of spatial distribution is used to find discrete function which is mapped with uniform distribution to obtain contrast enhancement. The algorithm proposed to obtain this is named as "Spatial Entropy-based Contrast Enhancement (SECE)" [1]. This algorithm does not alter the histogram of enhanced output with respect to original histogram and it gives natural look to the output with proper parameter selection. It has a margin for contrast improvement with no distortions in it. Contrast enhancement algorithm can be subdivided into two categories namely a) spatial domain algorithms and b) frequency domain algorithms. Some research works have focused to analyze the efficient method suitable for contrast enhancement. The most widely used image-domain contrast enhancement algorithm global histogram equalization (GHE) uses an input-to-output mapping derived from matching of the cumulative distribution function (CDF) of input image histogram to CDF of uniform distribution. Although GHE utilizes the available dynamic range of the image, it tends to over-enhance the image if there are large peaks in the histogram, resulting in a harsh and noisy appearance of output. Local histogram equalization (LHE) algorithms have been developed to address the afore mentioned problems [2] where a small window that slides over every image pixel sequentially and the histogram of pixels within the current position of the window is equalized. But sometimes it also enhances the noise present in the image and may produce undesirable checker-board effects. Adaptive Histogram Equalization (AHE) [4] has the advantage of controlling the level of contrast to avoid enhancing the noise present in the image but it produces visual artifacts in output. Weighted Threshold Histogram Equalization (WTHE) [3] removes the visual artifacts present in the image but requires proper parameter selection and does not preserve brightness. Brightness-preserving Histogram equalization with maximum entropy (BPHEME) [9] overcomes the above problem but sometimes it performs contrast stretching. In Histogram Modification Framework (HMF), contrast enhancement is treated as optimization problem to handle noise and stretching. It enhances only the global features and fails to enhance the minute details. In order to achieve both global and local enhancement at the same time, transform domain is applied after SECE. The transformation is a process that translates one object from a given domain to another. Three different transform domain (discrete cosine transform) contrast enhancement algorithms are proposed: Logarithmic transform

histogram matching(LTHM), Logarithmic transform histogram shifting(LTHS) and Logarithmic transform histogram shaping using Gaussian distribution (LTHSG). But these methods do not give efficient enhancement technique. DCT technique separates the image into parts (or spectral sub-bands) of different importance (with respect to the image's visual quality). The popular block-based DCT transform segments an image non overlapping block and applies DCT to each block. It gives result in three frequency sub-bands: low frequency sub-band, mid-frequency sub-band and high frequency sub-band and enhances separately. But this has the drawback that it does not handle sub-band image properly without proper parameter selection. In order to design a parameter-free contrast enhancement method, genetic algorithm (GA) is employed to find a target histogram that maximizes a contrast measure based on edge information. We call this method contrast enhancement based on GA (CEBGA) [8]. CEBGA suffers from thedrawbacks of GA-based methods, namely, dependence on initialization and convergence to a local optimum. These problems are overcome by an efficient transform called the Wavelet Transform (WT). The wavelet approach consists of first transforming the image into two wavelet coefficients relative to the horizontal and vertical wavelet bands are modified by multiplying by constant at scale and at pixel position. Finally the enhanced image is obtained by the inverse wavelet transform from the modified wavelet coefficients. Conventional Fourier transform provides only the frequency information. Temporal information is lost in this transformation. Unlike conventional Fourier transform, wavelet transforms are based on small waves called wavelets. It can be shown that we can both have frequency and temporal information by this kind of transform using wavelets. Wavelet transform is one of the best tool for us to determine where the low frequency area and high frequency area is present. And also it preserves the brightness and removes visual artifacts. It gives better quantitative and qualitative results [5].

This paper is organized as follows: Introduction is given in section I. Flow diagram of proposed method is given in section II. Section III presents the result of proposed method compared with the state-of-the-art contrast enhancement algorithm. Section IV gives the conclusion.

II. FLOW DIAGRAM FOR PROPOSED METHOD

The flow diagram depicts the process of the proposed method using SECE algorithm and Wavelet transform. To apply SECE algorithm an input color image is taken and converted into grayscale image. Histogram equalization is applied to the gray scale image and the entropy value is calculated. Then cumulative distribution function is found out to obtain output for SECE algorithm. Now 2D-DWT is applied to the image and the coefficients of wavelet transform are weighted [4] followed by inverse 2D-DWT to obtain globally and locally enhanced image.

A. *Module 1*:

An input colour image is taken with size X= {x(i,j) | $0 \le i \le H-1$, $0 \le j \le W-1$}, of size H x W pixels, where $x(i,j) \in [0,Z^+]$ and assume that X has a dynamic range of $[x_d, x_u]$ where $x(i,j) \in [x_d, x_u]$.

B. *Module 2: SECE algorithm for Global Contrast Enhancement*

It gives a global, computationally efficient spatial contrast enhancement method which performs enhancement using spatial location of gray levels of an image instead of direct use of gray-levels. The proposed global contrast enhancement algorithm is named as "Spatial Entropy-based Contrast Enhancement (SECE)". SECE produces naturally looking global contrast enhancement without any parameter selection. Furthermore, the algorithm does not alter the information structure of the processed histogram with respect to the original histogram.

1) The input image with specified size is taken to produce the output Y= {y(i,j) | $0 \le i \le H-1$, $0 \le j \le W-1$}, which has a better visual quality than X. The dynamic range of Y can be strtched or compressed into the interval $[y_d, y_u]$, where $y(i,j) \in [y_d, y_u]$, $y_d < y_u$ and $\{y_d, y\} \in [0, Z^+]$. In this work, the enhanced image utilizes the entire dynamic range, e.g. for an 8-bit image $y_d=0$ and $y_u=2^8-1=255$.

2) *Calculation of Spatial Histogram:* Let *X*= $\{x_1, x_2, \ldots, x_K\}$ be the sorted set of all possible K gray-levels that exist in an input image X where $x_1<x_1<\ldots<x_K$, where K is the number of the distinct gray-levels. The 2D spatial histogram of the gray-level x_k on the spatial grid of X is computed as

$$h= \{h_k(m,n) \mid 1 \le m \le M,\ 1 \le n \le N\} \quad (1)$$

where $m,n \in Z^+$, $h_k(m,n) \in [0,Z^+]$ is the number of occurrences of the gray-level x_k in the spatial grid located on the image region of [(m-1) H/M, m H/M]× [(n-1) W/N, n W/N]. The total number of the grids on 2D histogram is MN which is dynamically estimated using the number of distinct gray- levels K and the aspect ratio r= H/W, i.e.

$$N=\lfloor (K/r)^{1/2} \rfloor,\ M=\lfloor (Kr)^{1/2} \quad (2)$$

where the operator $\lfloor . \rfloor$ Rounds its argument towards the nearest integer.

3) *Spatial Entropy to find distribution function:* Using the 2D spatial histogram h_k, entropy measure S_k is computed for gray-level x_k according to

$$S_k= -\sum_{m=1}^{M}\sum_{n=1}^{N} h_k(m,n) \log_2 (h_k(m,n)), \quad (3)$$

which is used to compute a discrete function f_k according to

$$f_k= S_k / \sum^{K} S_l \quad (4)$$

$l=1, l \neq k$

The discrete function f measures the relative importance of the gray-level x with respect to the rest of the gray-levels x_l, $l \neq k$, L= 1,….,K. The discrete function f_k is further normalized according to

$$f_k \leftarrow f_k \Big/ \sum_{l=1}^{K} f_l \tag{5}$$

and cumulative distribution function F is defined as follows k

$$F_k = \sum_{l=1}^{k} f_l \tag{6}$$

4) *Mapping Function:* Using the cumulative distribution function F_k, x_k is mapped to y according to

$$y_k = \lfloor F_k (y_u - y_d) + y_d \rfloor \tag{7}$$

C. *Module 3: Wavelet transform for Global and local Contrast Enhancement*

SECE is designed for global contrast enhancement, thus a single transfer function is applied to the entire image. The algorithm provides contrast enhancement without distortion on output image. In order to achieve both global and local contrast enhancement we developed an automatic algorithm (SECEDWT) which employs SECE for global and 2D-DWT for local contrast enhancement. Wavelet can be regarded as the most efficient transform and it is based on sub-band coding. In the proposed method it is used for decomposition of an image into various sub-bands [6]. The input image with size H x W pixels is decomposed into four sub-bands using 2D-DWT transforms as approximations and detail coefficients. Approximate coefficients are high scale low frequency components of an image. The detailed coefficients are low scale high frequency components. Then the approximation coefficients are again decomposed at level j into four components and the detailed coefficients in three orientation (horizontal, vertical and diagonal). The 2D wavelet decomposition of an image is performed by applying 1D-DWT along the rows of the image first and then the results are decomposed along the columns [7].

LL	LH
HL	HH

Fig (a) Result of 2D-DWT

Apply mean filter on high pass components (detailed coefficients) of the input image to obtain various sub-bands such as L1H1, L1H2, L2H1, L2H2, H1L1, H1L2, H1H1, H1H2, H2L1, H2L2, H2H1, H2H2. Then applying the transform on the low-pass components (approximate coefficients) L1H1, L1L2, L2L1, L2L2.

D. *Module 4: Wavelet coefficient weighting*

Wavelet coefficients are formed for each part will be processed on the resultant high pass components only (L1H1, L1H2, L2H1, L2H2, H1L1, H1L2, H1H1, H1H2, H2L1,

H2L2, H2H1, H2H2) by applying mean filter followed by weighting the coefficients of both low pass and high pass components.

L1L1	L1L2	L1H1	L1H2
L2L1	L2L2	L2H1	L2H2
H1L1	H1L2	H1H1	H1H2
H2L1	H2L2	H2H1	H2H2

E. *Module 5: Inverse Wavlet transform to obtain the output*

After weighting the coefficients of the components, inverse Wavelet transformation is taken which gives the reconstructed image. The image at high frequency produces more noise, so it is taken under low frequency.

III. Results And Discussion

For obtaining better results various transforms has been compared with wavelet transform to improve the contrast of gray scale image.

A) Objective measure

1) **Calculation of Entropy**

Entropy is the average amount of information contained in each pixel. Entropy is calculated from the gray levels of an image which is spatially distributed, is mapped to the uniform distribution function which gives the final contrast enhanced image. *The entropy measure S_k is computed for gray-level x_k as,*

$$S_k = -\sum_{m=1}^{M} \sum_{n=1}^{N} h_k(m,n) \log_2 (h_k(m,n))$$

Figure: 1

Figure: 2

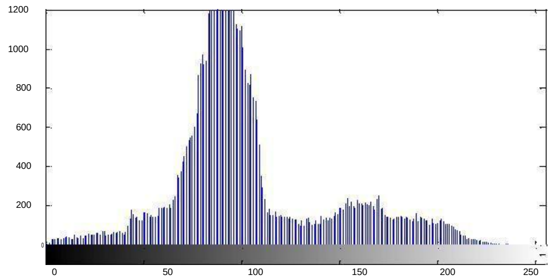


Figure: 3

1)Input Image 2) Gray scale Image 3) Spatial histogram

HE	WTHE	GHE	BPHEME	FHSABP	DWT
34.88	24.88	16.51	26.15	26.07	6.3699

Table:1 *Tabulation of Entropy values for different methods*

2) COMPUTATIONAL TIME IN SECONDS

Computational complexity is an important parameter commonly estimated by counting the number of elementary operations performed by the algorithm, where an elementary operation takes a fixed amount of time to perform. The results of the computation time for various methods are tabulated in Table:5.

Figure: 4 Results of computation time for girl image (a)GHE (b)HMF (c)AHE (d)WTHE (e)SECE (f)SECEDCT (g)SECEDWT

GHE	HMF	AHE	WTHE	SECE	SECEDCT	SECEDWT
0.181	0.343	0.579	0.014	0.361	0.430	0.216

Table:5 Computational time in seconds

B) SUBJECTIVE MEASURE

1) Brightness Analysis

Brightness is an attribute of visual perception in which a source appears to be radiating or reflecting light. In other words, brightness is the perception elicited by the luminance of a visual target. This is a subjective attribute/property of an object being observed.

(a) (b) (c) (d) (e)

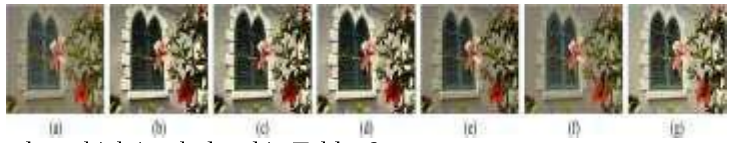
Figure:4 Brightness result for the image eagle: (a)HE (b)WTHE (c)GHE (d)BPHEME (e)DWT

HE	WTHE	GHE	BPHEME	FHSABP	DWT
Bad	Bad	Bad	Fair	Fair	Good

Table:2 *Tabulation for Brightness analysis*

2) MEAN OPINION SCORE (MOS)

The Mean Opinion Score (MOS) is the Arithmetic mean of the subjective tests and can range from 1 to 0 i.e. worst to best Table:3. Comparing to other methods DWT has greater MOS



value which is tabulated in Table: 3.

Figure: 5 MOS result for the image window: (a)GHE (b)BPHEME (c) FHASBP (d)HMF (e)CEBGA (f)GMM (g)DWT

MOS	Quality	Impairment
5	Excellent	Imperceptible
4	Good	Perceptible but not annoying
3	Fair	Slightly annoying
2	Poor	Annoying
1	Bad	Very annoying

Table:3 Tabulation of MOS and its impairment

GHE	BPHEME	FHASBP	HMF	GMM	DWT
2.7±1.3	2.6±1.4	2.5±1.4	3.6±1.1	4.0±1.1	5.0±0.5

Table:4 *Tabulation for MOS values for various techniques*

IV. CONCLUSION

Wavelet analysis communicates knowledge that time frequency methods such as Fourier analysis cannot. The disadvantages of the FT are: Gives us the global picture, no local information. Most real life signals are not combinations of sinusoids. Poor performance when the frequency changes with time. Wavelets have compact support, Fourier series do not. Some wavelet transforms act in a manner which divides a signal into those components which are significant in time and space and those that contribute less. This feature enables wavelets to be very useful in applications such as noise removal, edge detection and data compression. In general, wavelets are beneficial when used to obtain further information from signal that is not readily available in the raw signal. The transform of the signal is just another way of representing the signal. It does not change the information content present in the signal. The transformation product enables spectrum analysis of the signal and spectral behavior of the signal in time. It has computational time of 0.216 and entropy of 6.3699 which is less than the discrete cosine transform. Wavelets are localized waves that have their energy concentrated in time or space and are well suited to analysis of transient signals. To cite one example, tide forecasting is performed using wavelets. The ripples and trends in the ocean waters are transient and in most of the image processing applications. Also used in the field of astronomy and satellite image processing.

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