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Proposed Algorithm for Image Enhancement in Frequency domain

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Abstract

This paper presents an algorithm for gray-scale image enhancement in frequency domain using Discrete Cosine Transform (DCT) depending on the definition of contrast measure in DCT domain. This algorithm introduces an efficient method for brightening darkened regions of images (which result from bad lighting scene) without saturation the normal regions.

The proposed algorithm dividing the image into nonoverlapping (8×8 pixel) blocks, for each block, the enhancement factor is computed by using a proposed equation. The enhancement factor is varied according to the mean of the block. The blocks with low mean (dark blocks), get high enhancement factor while the brighten blocks get low enhancement factor.

الخلاصـــــة

يقدم هذا البحث خوارزميه لتحسين الصور الرمادية باستخدام تحويل جيب التمام المتقطع بالاعتماد على مقياس التباين في مجال تحويل جيب التمام المتقطع في مجالِ الترددِ . تقدم هذه الخوارزميه طريقه كفوءه لزيادة سطوع الأجزاء المظلمة في الصورة (والتي تحدث بسبب رداءة الإضاءة) بدون التأثير على المناطق الطبيعية.

تقسم الخوارزمية المقترحة الصورة إلى مقاطع بأبعاد (٨x٨ عنصر صورة) غير متداخلة، ثم يتم حساب عامل التحسين بالاعتماد على معادلة مقترحة. عامل التحسين يتغير وفقاً للمتوسط الحسابي لكل مقطع. المقاطع التي يكون فيها المتوسط الحسابي قليل (المقاطع المظلمة) تحصل على عامل تحسين عالي، بينما المقاطع عالية السطوع تحصل على عامل تحسين قليل.

1. Introduction

Image enhancement techniques are used to emphasize and sharpen image features for display and analysis. Image enhancement is the process of applying these techniques to facilitate the development of a solution to a computer imaging problem. Consequently, the enhancement methods are application specific and are often developed empirically [1]. Enhancement methods operate in the spatial domain by manipulating the pixel data or in the frequency domain by modifying the spectral components. Some enhancement algorithms use both the spatial and frequency domains [1]. One of the most widely used algorithms for image enhancement is global histogram equalization [2], which adjusts the intensity histogram to approximate a uniform distribution. This algorithm yields poor local performance in terms of detail preservation, because it treats all regions of the image equally. The main disadvantage of global histogram equalization is that the global image properties may not be appropriately applied in a local context [3]. Due to this drawback of global histogram equalization, several local image enhancement algorithms have been proposed [3-9]. These algorithms may be classified into those that enhance contrast directly [3,4] and those that enhance contrast indirectly [5-9].

In direct contrast enhancement methods measure the image contrast before enhancement, which is the main step in these methods. Several methods used for contrast measure, one of them are Michelson contrast measure [10], and the other is weber contrast measure [11]. The Michelson contrast measure is used to measure the contrast of a periodic pattern such as a sinusoidal grating, while the Weber contrast measure assumes a large uniform luminance background with a small test target [12]. Other methods used for complex images [6,7,8,11, and 12], a local contrast measure is proposed in [7], where the contrast is measured using the mean gray values in two rectangular windows centered on a given pixel. Another contrast measure based on a local analysis of edges is defined in [8] and is derived from the definition in [7]. The contrast measure is defined as the ratio of high frequency content and low frequency content and the bands of the DCT matrix [13].

In this paper an algorithm is proposed for image enhancement using DCT by modifying the previous algorithm of [13]. The proposed algorithm is parameter free (required no parameter to be entered by the user) while the previous algorithm required an image enhancement control factor to be chosen by the user. When control factor is greater than (1), the image will be enhanced. When it's less than (1), the image will be softened [13].

2. The Proposed Algorithm

Image enhancement methods may be classified into those that enhance contrast directly and those that enhance contrast indirectly. Direct contrast enhancement methods [17-19] measure the image contrast before enhancement.

In this paper, a new direct contrast enhancement method based on a definition of image contrast in the DCT domain is introduced.

The proposed algorithm contains the following stages:

1. Dividing the input image into nonoverlapping M blocks of (8X8) pixels.
2. Computing enhancement factor (λ).
3. Computing DCT coefficients of all blocks.
4. Applying the Enhancement algorithm.
5. Computing inverse DCT of all blocks to form the enhanced image.

2-1 Computing the Enhancement Factor

The resultant image is depending upon the enhancement factor. The enhancement factor in the previous work selected by the user and fixed for all blocks [13]. According to the experiment done using this method (some of experiments are shown in **Figs.(1,2)**), it is noted that its difficult to select appropriate enhancement factor, so its required to repeat the experiment many times to get the desired or enhanced image. Also, for the image with darkened areas it's found that the resultant image is blurred, therefore several experiments are done to select appropriate function that used to compute the enhancement factor, which is varied according to the lightness of the blocks and don't remain constant for the whole image, and also make it flexible for a wide bands of images. The goal here is to find appropriate function that satisfy best enhancement of wide range images and make the enhancement factor varied automatically according to the properties of each block. After these many experiments, it's found that the following equation can satisfy best enhancement and low computation time for high range images.

$$\lambda = (3)^{\exp(-3*m)} \quad \text{.......... (1)}$$

where:

λ: is the enhancement factor,
m: is the mean of the block, and
*exp(-3*m): is the inverse of natural logarithm.*

From eq.(1) the enhancement factor is varied according to the lightness of the image parts, the darkened parts of the image get high enhancement factor and vise versa .

Figure (1-a) Original image

Figure (1-b) Enhanced image using original algorithm with λ =2

Figure (1-c) Enhanced image using original algorithm with λ =3

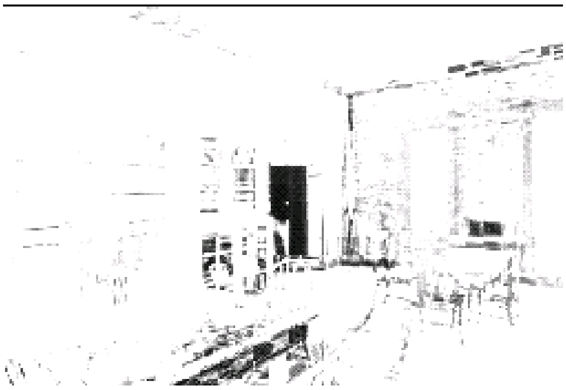

Figure (1-d) Enhanced image using original algorithm with λ =4

Figure (1-e) Enhanced image using the proposed algorithm

Figure (2-a) Original image

Figure (2-b) Enhanced image using original algorithm with λ =2

Figure (2-c) Enhanced image using original algorithm with λ =3

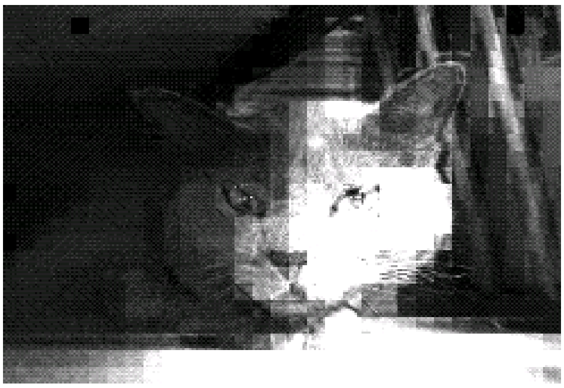

Figure (2-d) Enhanced image using original algorithm with λ =4

Figure (2-e) Enhanced image using the proposed algorithm

2-2 Computing DCT Coefficients

The DCT coefficients represent the spatial frequency content of the image in a similar way to the coefficients in one quadrant of the 2-D Fourier domain. The coefficients at location (0,0) represents the DC level of the block, and the other coefficients represents spatial frequencies that increase with their distance from the DC level [13]. After computing the enhancement factor in a spatial domain the next step is computing the coefficients of the DCT of the (8 X 8) blocks.

Let x (i, j) be an (8X8) block in the original image, and DCT transform of it is d(k,l), the 2-DCT transformation is expressed as [13,14].

$$d(k,l) = \frac{c(k)c(l)}{4} \sum_{i=0}^{7} \sum_{j=0}^{7} x(i,j) \cos\left(\frac{(2i+1)k\pi}{16}\right) \cos\left(\frac{(2j+1)l\pi}{16}\right) \quad \text{............................ (2)}$$

where:

k , l=0,1,…7 , and

$$c(k) = \begin{cases} 1/\sqrt{2} & \text{if } k = 0 \\ 1 & \text{otherwise} \end{cases} \quad \text{.. (3)}$$

The DCT inverse transformation can be expressed as:

$$x(i,j) = \sum_{k=0}^{7} \sum_{l=0}^{7} \frac{c(k)c(l)}{4} d(k,l) \cos\left(\frac{(2i+1)k\pi}{16}\right) \cos\left(\frac{(2j+1)l\pi}{16}\right) \quad \text{.......................... (4)}$$

where:

i, j= 0,1,2 …7.

From eq.(3), we see that each represents the contribution corresponding to the k,l th waveform [13] and the coefficients in the output DCT block are arranged left to right, and top to bottom in order of increasing spatial frequencies in the horizontal and vertical spatial dimensions, respectively.

2-3 Contrast Measure

The spatial frequency properties of the DCT coefficients provide a natural way to define a contrast measure in the DCT domain. It is known that the human visual detection depends on the ratio between high-frequency and low-frequency content [11]. Thus, the contrast measure can be defined as the ratio of high and low-frequency content in the bands of the DCT matrix. Then the contrast measure of the various bands is given by [13, 14]:

$$C_n = \frac{E_n}{E_{n-1}} \quad \text{.......... (5)}$$

where:

C_n: is the local contrast measure in the n-th band, $1<n<14$ (where n represent the diagonal coefficient of the (8X8 block) except the element (0,0) which represent the DC. cofficient), and the average spatial band amplitude over a spectral band is given by :

$$E_n = \frac{\sum_{k+l=n} |d(k,l)|}{N} \quad \text{.......... (6)}$$

where:

$$N = \begin{cases} n+1 & n<8 \\ 14-n+1 & n \geq 8 \end{cases}$$

The contrast of the various bands defined in the DCT block be:

$$C = (C_1, C_2, \ldots\ldots, C_{14}) \quad \text{.......... (7a)}$$

and the contrast of the enhanced image be:

$$R = (R_1, R_2, \ldots\ldots, R_{14}) \quad \text{.......... (7b)}$$

Then the relation between C and R is:

$$R_n = \lambda\, C_n \quad \text{.......... (8)}$$

or we can define that:

$$R_n = \frac{F_n}{F_{n-1}} = \lambda C_n = \frac{\lambda E_n}{E_{n\text{-}1}} \quad \text{.......... (9)}$$

or

$$F_n = \frac{\lambda E_n}{E_{n-1}} F_{n-1} \quad \text{.......... (10)}$$

where:

F_n: is the average spatial band amplitude over a spectral band of the resultant block, and

$E_0=F_0$, then the enhanced DCT coefficients ($\bar{d}(k,l)$) can be computed from

$$\bar{d}(k,l) = \frac{\lambda E_n}{E_{n-1}} F_{n-1}\, d(k,l) \quad \text{.......... (11)}$$

where:

d(k,l): represent the enhanced DCT coefficients of the ((8×8 pixel) blocks) under processing.

The block diagram of the proposed algorithm is shown in **Fig.(3)**. The process repeated for all image blocks.

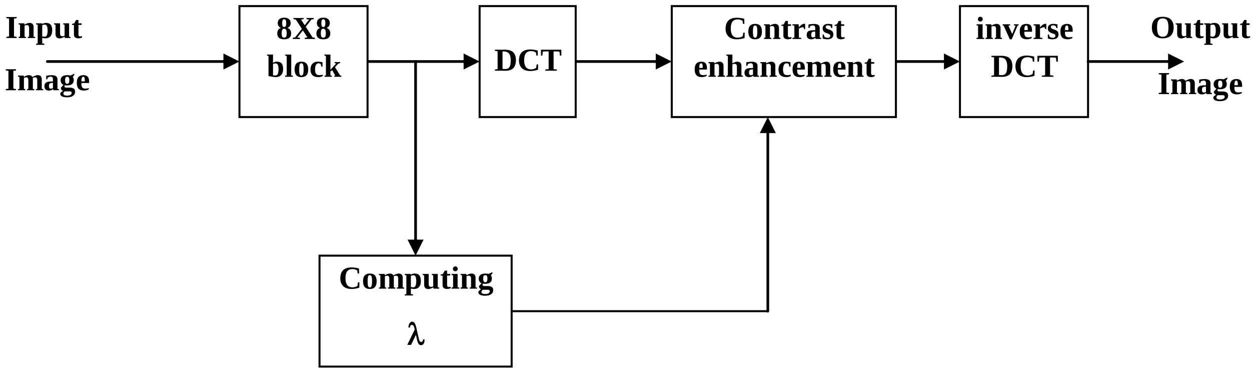

Figure (3) Block diagram of the proposed algorithm

3. Results and Discussion

The original algorithm and the proposed algorithm are applied to a set of images with different gray level distribution. In this paper two images are listed one of them very dark and the other is medium darkness. The image in **Fig.(1-a)** processed using the previous algorithm with different values of enhancement factor (2, 3 and 4) as shown in **Figs.(1-b to 1-d)**. **Figure (1-b)** shows this image by applying the previous algorithm when enhancement factor (2), the resultant image here enhanced with a little degree. When the enhancement factor increased to 3 or 4 as shown in **Figs.(1-c and 1-d)** the resultant image distorted, especially when enhancement factor=4 and lost more details from this image. When the same image processed by the proposed algorithm (**Fig.(1-e)**), the resultant image is better than the original one and more details appear with good degree. In **Figs.(2-a to 2-e)** dark image is processed using two algorithms, **Fig.(2-a)** shows original image, **Figs.(2-b, 2-c and 2-d)** shows the resultant image using the original algorithm when enhancement factor (2, 3 and 4), its clear that the dark regions of the original image don't affected by this process, while the other regions are blurred which is a bad result and the features of the image isn't clear. **Figure (2-e)** shows the same image when processed by the proposed algorithm, its clear that the resultant image enhanced with a good degree and many objects in this image are appearing. The comparison between the results obtained from the previous figures shows that the proposed algorithm has better performance than the original algorithm.

4. Conclusions

The image enhancement method using contrast measure in DCT domain has been implemented. The proposed algorithm is easy for application since its required no parameter to be varied and selected by the user which is reduce the time of processing since the original image is required to be repeated many times to select a proper contrast enhancement factor. Also this algorithm provides good performance especially for darkened images, and the Enhancement factor is computed according a proposed function depends on the mean of the image (8X8) blocks.

5. References

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