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A contrast enhancement method for compressed images

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Abstract: An image contrast enhancement algorithms for BDCT (Block Discrete Cosine Transform) based compressed images is presented. Contrast enhancement is achieved by modifying the quantized DCT coefficients based on a contrast measure defined within the DCT domain. The performance is compared with other methods and better visual quality is obtained.

Keywords: Compressed domain, contrast measure, human vision system, image enhancement

Classification: Science and engineering for electronics

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1 Introduction

The goal of the image enhancement is to improve the visual appearance so that the processed image is better than the original one for a specific application or set of objectives such as analysis, detection, segmentation, and recognition or the visually impaired. Many image enhancement algorithms

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have been proposed. One of the most widely used algorithms is global histogram equalization [1], the basic idea of which is to adjust the intensity histogram to approximate a uniform distribution. It treats all regions of the image equally and, thus, often yields poor local performance in terms of detail preservation. Therefore, several local image enhancement algorithms have been introduced to improve enhancement [2, 3]. In [6], Tan developed an image enhancement method based a contrast measure in the DCT domain. But the method didn't consider the local characteristics of the block, it often produces unpleasant blocking artifacts in smooth regions.

In this letter, the contrast measure is defined as the ratio of high-frequency content and low-frequency content in the bands of the DCT matrix. Our contrast measure also has a multiscale structure that corresponds with the human vision system as in [5]. Based on this contrast measure, an image enhancement algorithm for direct application to the DCT domain is developed. Each block is enhanced according to its block classification. It can suppress some unpleasant artifacts and produces visually better images.

The paper is organized as follows: Section II presents our proposed image contrast enhance algorithm, and in section III, the experiments and discussion is given. Finally in section IV, the conclusion is presented.

2 Image contrast enhancement in DCT domain

Let $B_{i,j}$ be an 8×8 block in the original image of size $8M \times 8N$. The DCT coefficients of the spatial block $B_{i,j}$ are $F(u,v)$. $u,v = 0,1,\ldots,7$, $i = 0,\ldots,M-1$, $j = 0,\ldots N-1$. The DCT coefficients have several different spatial features since DCT coefficients provide the frequency domain information in the block. $F(0,v)$, $F(u,0)$, and $F(u,v)$, $1 \le u,v \le 7$ describes the horizontal high frequency information, vertical high frequency information, and the mixed horizontal and vertical high frequency information, respectively. Let

$$
\begin{aligned}
K_{hedge} &= \sum_{v=1}^{7} |F(0,v)| \\
K_{vedge} &= \sum_{u=1}^{7} |F(u,0)| \\
K_{texture} &= \sum_{u=1}^{7}\sum_{v=1}^{7} |F(u,v)|
\end{aligned}
\tag{1}
$$

$K = \max(K_{hedge}, K_{vedge}, K_{texture})$. If $K < T_h$, the block is described as a smooth block; else, the block is described as a high activity block, T_h is a threshold. For a high activity block, if $K = K_{hedge}$, the block is regarded as a horizontal edge block; then, if $K = K_{vedge}$, the block is regarded as a vertical edge block; else, the block is regarded as a texture block. We define

$$
\begin{cases}
\alpha_h = K_{hedge}/(K_{hedge} + K_{vedge} + K_{texture}) \\
\alpha_v = K_{vedge}/(K_{hedge} + K_{vedge} + K_{texture}) \\
\alpha_t = K_{texture}/(K_{hedge} + K_{vedge} + K_{texture})
\end{cases}
\tag{2}
$$

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2.1 Contrast Measure in the DCT Domain

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 [5]. Thus, the contrast measure can be defined as the ratio of high and low-frequency content in the bands of the DCT matrix. Our contrast measure is defined on each band. The contrast at the n th band ($n \geq 1$) is defined as [6]:

$$c_n = \frac{E_n}{\sum\limits_{k=0}^{n-1} E_k} \tag{3}$$

where,

$$E_k = \frac{\sum\limits_{u+v=k} |F(u,v)|}{L} \tag{4}$$

is the average amplitude over a spectral band. Fig. 1 illustrates the block classification and the definition of E_k.

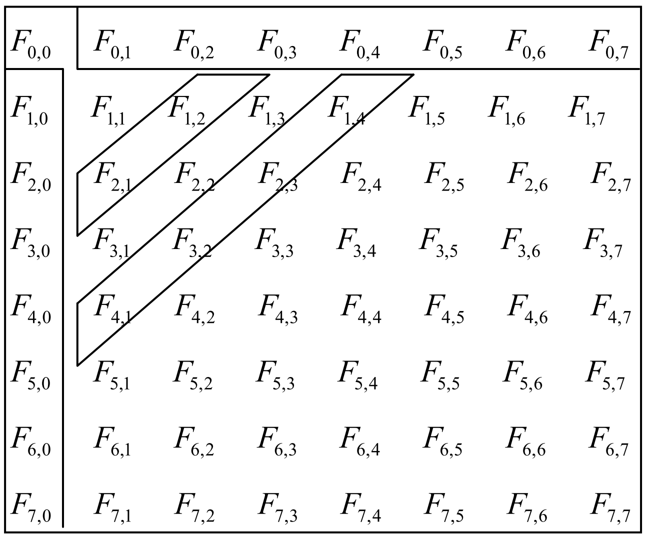

Fig. 1. DCT output block.

For a smooth block,

$$L = \begin{cases} k+1, & k < 8 \\ 14-k+1, & k \geq 8 \end{cases}, \quad n = 1, \ldots, 14, \quad k = u+v, \quad k \geq 1 \tag{5}$$

for an edge block, we define the contrast in horizontal , vertical and texture component, respectively.

$$n = 1, \ldots, 7,\ k = v,\ k \geq 1,\ L = 1,\ \text{In horizontal component} \tag{6}$$

$$n = 1, \ldots, 7,\ k = u,\ k \geq 1,\ L = 1,\ \text{In vertical component} \tag{7}$$

$$L = \begin{cases} k-1, & k < 9 \\ 14-k+1, & k \geq 9 \end{cases},$$
$$n = 2, \ldots, 14,\ k = u+v,\ k \geq 2,\ \text{In texture component} \tag{8}$$

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Here, for the sake of simplicity, we assume that visual acuity is isotropic. The definition provides a local contrast measure for each band in the DCT domain.

2.2 Image Enhancement in the DCT Domain

We consider direct enhancement in the compressed domain. The proposed image enhancement algorithm is based on the contrast measure proposed above. For a block, we enhance it differently according to the block classification described above. Let the contrast of the original image block be $C = \{c_n\}$, where c_n is the contrast at a specific frequency band corresponding to E_n, and let the contrast of the enhanced block be denoted by $\bar{C} = \{\bar{c}_n\}$, n is defined as in (5)-(8). We assume to enhance the contrast uniformly for all frequencies, then,

$$\bar{c}_{i,n} = \lambda(1+\alpha_i)c_{i,n} \tag{9}$$

According to (3), (9) can be expressed as:

$$\frac{\bar{E}_{i,n}}{\sum_{t=0}^{n-1}\bar{E}_{i,t}} = \bar{c}_{i,n} = \lambda(1+\alpha_i)c_{i,n} = \frac{\lambda(1+\alpha_i)E_{i,n}}{\sum_{t=0}^{n-1}E_{i,t}} \tag{10}$$

$$\text{Let } H_{i,n} = \frac{\sum_{t=0}^{n-1}\bar{E}_{i,t}}{\sum_{t=0}^{n-1}E_{i,t}}, \tag{11}$$

Equation (10) can be stated as:

$$\bar{E}_{i,n} = \lambda(1+\alpha_i)H_{i,n}E_{i,n}, \tag{12}$$

From (4), we can obtain the enhanced DCT coefficients $\bar{F}(u,v)$ as

$$\bar{F}_i(u,v) = \lambda(1+\alpha_i)H_{i,n}F_i(u,v), \quad i = s,h,v,t \tag{13}$$

where, $\alpha_s = 0$.

3 Experiments results and discussion

In our experiments, a gray image compressed using JPEG was used to evaluate the performance of the proposed algorithm. The size of the image is 256×256. We compared the proposed method with other two DCT-based methods: one is the enhancement operator (EO) method [4]. Let $F(u,v)$ be the original DCT coefficients, the enhancement operator is expressed as $O(u,v)$,

$$O(u,v) = \log^{\beta}[|F(u,v)|^{\lambda} + 10] \tag{14}$$

The other is the one used in [6], which is similar to the method we used in smooth block. Fig. 2 (b) displays the enhanced image by the EO method when $\lambda = 1.5$, $\beta = 0.8$. Fig. 2 (c) shows the enhanced image by Tan's method in [6]. Fig. 2 (d) is the enhanced image using our method when $\lambda = 1.5$. Comparing the enhanced images from the proposed method with

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this two DCT domain enhancement methods, one can see that with the EO method, some regions appear overly darkened and others overly lightened, and some edge details appear to be blurred. Unnatural enhancement can be seen around the hat and hair. From the result in Fig. 2 (c), one can see that compared to the original image, the enhanced image clearly show unnatural enhancement. There are unpleasant artifacts (bright noise) in the resultant image, such as in the shoulder and head, but these artifacts can be suppressed with our method. Moreover, there also appears ring effect in the edge regions. The larger λ is, the more serious the effects are. Compared with Tan's method, our method can produce an enhanced image with improved visual quality. It can suppress the blockness and grid effects in the smooth regions and ring noise in the edge regions. It can be seen that more details are preserved and the edges are clearer, which can be distinct around the hair. Result from Fig. 2 (d) indicates that the proposed algorithm has preserved the brightness well and yielded a more natural enhancement. The simulation

Fig. 2. (a) Decompressed image with PSNR = 31.97

Fig. 2. (b) Image enhanced with enhancement operator method

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results indicate that our method performs better than EO and Tan's. It can provide to avoid annoying artifacts and preserve the brightness well and give natural enhancement in most part of the image, Due to the limit of the display space, the result of these figures is not clear, however in the monitor, the comparisons are distinguishable and clearer.

Fig. 2. (c) Image enhanced with the method in [6]

Fig. 2. (d) Image enhanced with proposed method

4 Conclusion

The comparative analysis shows the merit of our proposed approach. It can be used to any BDCT based real-time applications.

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