Multiscale Contrast Enhancement for Compressed Digital Images with Block Artifacts Consideration

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Abstract - A simple and efficient algorithm is presented for contrast enhancement, of JPEG compressed images, in the Discrete Cosine Transform (DCT) domain. The algorithm enhances the DCT coefficients in accordance with their band importance. Since uniformly modifying all the frequency bands causes block artifacts, therefore, the low frequency bands are dealt with differently than the rest of the frequency bands. As the enhancement is done in the decompression stage, compressibility of the original image is not affected. Subjective and objective tests performed on various images validate the concept of multiscale contrast enhancement.

KEYWORDS

Contrast Enhancement, Digital Image Enhancement, Discrete Cosine Transform (DCT) and JPEG Compression.

I. INTRODUCTION

Image enhancement is the name of modifying certain features of an image such that it gives better look to the human visual system (HVS). Contrast enhancement is one such feature among the various features of an image, modification of which can produce better view of the image. In most of the cases, contrast enhancement may play the preprocessing role for later processing steps of the image enhancement.

Several methods are available for image enhancement in the spatial domain. Global Histogram Equalization [1] enhances the contrast of an image by rescaling the original image so that the histogram of the enhanced image follows some desired form. Since it treats all regions of the image equally, it often yields poor local performance due to the minimum detail preservation and performs not that good in the local context [2]. Some of the techniques are based on local contrast measure [3], while Beghcladi proposed a contrast enhancement technique via edge detection [4].

Compressed domain techniques for image enhancement usually operate on the transform coefficients of the images that are compressed by various transform methods. These include α-rooting algorithm [5-6] and modified unsharp masking [2].

J.Tang et. Al [7] presented a measure in the DCT domain for the contrast enhancement of JPEG compressed images. The contrast enhancement is done at the decompression stage which preserves the compressibility of the original image. Though this method improves the contrast of the image very well, it does not take into account the blocking artifacts that might appear due to the uniform modification of all the DCT bands i.e. it manipulates DCT coefficients using a single measure without considering the sensitivity of HVS to low-frequencies.

In this paper, we modify the DCT coefficients according to their band importance, instead of modifying them uniformly, for contrast enhancement of the digital images in compressed domain. The contrast enhancement is improved by giving more importance to the coefficients in the higher frequency bands.

This paper is organized as follows: Section 2 introduces JPEG image compression scheme. Section 3 describes contrast enhancement in DCT domain, the used algorithm and the proposed modification for contrast enhancement. Performance of the proposed scheme is given in section 4 and section 5 concludes the paper.

II. JPEG – DCT BASED IMAGE COMPRESSION

In this section, we present a brief review of JPEG, a DCT-based image compression technique. The idea of JPEG can easily be extended to other DCT-based image compression standards, such as MPEG 2, and H.26X.

A. JPEG Compression

A JPEG compression system consists of two parts, an Encoder and a Decoder. In the encoder, the image is partitioned into non-overlapping blocks of 8x8 pixels. Then DCT is performed on each 8x8 block, followed by the quantization of these DCT coefficients. Finally, the quantized coefficients are zig-zag scanned and entropy encoded.

In order to reconstruct the image, the decoder decodes the compressed image using entropy decoding. Dequantization is performed by point wise multiplication with the quantization table, and then inverse DCT-Transform is applied to obtain the image back.

The two-dimensional DCT of an 8 x 8 block $I_{j,k}$ in an original image is given by:

$$F(u,v) = \frac{1}{4} C(u)C(v) \sum_{j=0}^{7} \sum_{k=0}^{7} I(j,k) \cos\left\{\frac{\pi}{8}[u(j+\frac{1}{2})]\right\} \cos\left\{\frac{\pi}{8}[v(k+\frac{1}{2})]\right\}$$

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where $u,v = 0, 1,\ldots, 7$, and

$$C(n) = \begin{cases} 1/\sqrt{2} & for \;\; n = 0 \\ 1, & otherwise \end{cases}$$

The inverse DCT transformation can be written as:

$$I(j,k) = \frac{1}{4} C(u)C(v) \sum_{j=0}^{7} \sum_{k=0}^{7} F(u,v) \cos\left\{\frac{\pi}{8}[u(j+\frac{1}{2})]\right\} \cos\left\{\frac{\pi}{8}[v(k+\frac{1}{2})]\right\}$$

Here $j,\ k = 0, 1\ldots7$.

The coefficient F_{00} in the upper left corner of an 8 x 8 DCT block is called the "DC Coefficient", and the other 63 elements are called "AC Coefficients". The DC coefficient contributes for the average value of a single block in the original image, while the AC coefficients depend on the variations in gray levels.

The DCT coefficients in each frequency band vector have approximately similar spatial frequency properties. If only one frequency band is selected and an image block is reconstructed using the selected band, the reconstructed block can be thought of as bandpass version of the original block with frequency n, where $n = u + v$. The frequency contents of the bandpass image block correspond with higher frequencies as the band number increases.

$$\begin{bmatrix} F_{00} & F_{01} & F_{02} & F_{03} & F_{04} & F_{05} & F_{06} & F_{07} \\ F_{10} & F_{11} & F_{12} & F_{13} & F_{14} & F_{15} & F_{16} & F_{17} \\ F_{20} & F_{21} & F_{22} & F_{23} & F_{24} & F_{25} & F_{26} & F_{27} \\ F_{30} & F_{31} & F_{32} & F_{33} & F_{34} & F_{35} & F_{36} & F_{37} \\ F_{40} & F_{41} & F_{42} & F_{43} & F_{44} & F_{45} & F_{46} & F_{47} \\ F_{50} & F_{51} & F_{52} & F_{53} & F_{54} & F_{55} & F_{56} & F_{57} \\ F_{60} & F_{61} & F_{62} & F_{63} & F_{64} & F_{65} & F_{66} & F_{67} \\ F_{70} & F_{71} & F_{72} & F_{73} & F_{74} & F_{75} & F_{76} & F_{77} \end{bmatrix}$$

Fig. 1. 8x8 DCT output block

III. CONTRAST ENHANCEMENT IN DCT DOMAIN

Our proposed image enhancement algorithm is based on the contrast measure presented by J.Tang. We first review that contrast enhancement and then present our modification in the method.

A. *Contrast Measure*

The HVS detects the details of the scene based on the ratio between high-frequency and low-frequency contents. Therefore, the spatial frequency characteristics can be used to define a relative measure of scene contents. For this purpose, the 64 coefficients in an 8 x 8 DCT block are classified into 15 frequency bands, as shown in Fig.1**.** The first band consists of the dc coefficient F_{00}, second band contains elements F_{01} and F_{10}, third band consists of F_{02}, F_{11} and F_{20} and so on. The number of elements in each spectral band can be obtained by:

$$N = \begin{cases} k+1, & k < 8 \\ 15-k, & k \geq 8 \end{cases} \qquad (1)$$

The local contrast measure of J. Tang is defined on each band except band number 0 (F_{00}). The contrast at *nth* band is defined as:

$$c_n = \frac{E_n}{\sum_{k=0}^{n-1} E_k} \qquad (2)$$

Where

$$E_k = \frac{\sum_{u+v=k} |F(u,v)|}{N} \qquad (3)$$

is the average amplitude over a spectral band.

This contrast measure c_n in the *nth* band is the ratio of the frequency content of the bandpass image block obtained by the *nth* band to that of the lowpass image block. Let the contrast of the original block be $C = (c_1, c_2, \ldots, c_{14})$, where c_n is the contrast at the *nth* frequency band corresponding to E_n, and let the contrast of the enhanced block be denoted by $\overline{C} = (\overline{c}_1, \overline{c}_2, \ldots, \overline{c}_{14})$.

The method presented by J.Tang enhances the contrast uniformly for all frequency bands as:

$$\overline{c}_n = \lambda . c_n \qquad (4)$$

B. *Proposed Modification*

Our objective of contrast enhancement has the following two purposes:

1. To effectively enhance the contrast of the image in such a way as to avoid block artifacts in the resultant image.
2. To enhance the image details by modifying the DCT coefficients according to their band importance.

This leads us to define a multiscale contrast enhancement factor that not only avoids block artifacts in the image, but also enhances the details of the image.

Eq. (4) can thus be modified as follows:

$$\overline{c}_n = \lambda_n c_n \qquad (5)$$

resulting in:

$$\frac{\lambda_n E_n}{\sum_{k=0}^{n-1} E_k} = \overline{c}_n = \lambda_n c_n = \frac{\overline{E}_n}{\sum_{k=0}^{n-1} \overline{E}_k} \qquad (6)$$

where λ_n is the contrast enhancement factor for the *nth* band. Eq. (6) can be formulated as:

$$\overline{E}_n = \lambda_n H_n E_n, \quad n \geq 1 \qquad (7)$$