A New Contrast Measure Based Image Enhancement Algorithm in the DCT Domain*

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Abstract - *In this paper a new algorithm is presented for image enhancement in the discrete cosine transform (DCT) domain. The algorithm is based on a novel contrast measure that is defined for each DCT coefficient. This algorithm can be applied to the enhancement of images compressed with JPEG and it is especially useful when it is applied to enhance the direction contrast of the images. Experimental results show the effectiveness of the proposed algorithm.*

Keywords: Image enhancement, DCT, JPEG/MPEG, contrast measure, direction contrast.

1 Introduction

Image enhancement has been applied successfully to different fields such as medical field, industry and military field [7] [8] [9]. Many methods have been proposed for image enhancement in the past decade. These methods can be mainly divided into two categories: spatial domain methods and frequency domain methods [1] [2]. Spatial domain methods work directly on pixels while frequency domain methods work on transform of the original image, such as discrete Fourier transform (DFT), discrete wavelet transform (DWT) or discrete cosine transform (DCT) and so on [1].

Among the frequency domain methods, image enhancement in the DCT domain has more advantages than other methods when it is applied to enhance the images compressed by DCT based compression methods such as JPEG/MPEG. DCT coefficients can be obtained directly from JPEG/MPEG bit stream without performing the transform, as is often the case with other transform based image enhancement methods, thus image enhancement in the DCT domain can get higher speed. Another advantage is the low complexity of computation [6]. Given a majority of zero-valued DCT coefficients after quantization in JPEG/MPEG, much less coefficients need to be processed than in other domains [6].

This paper provides a new image enhancement algorithm based on a contrast measure in the DCT domain. Compared with other contrast measures, the measure adopted in this paper can be employed to measure the direction contrast. Thus, the image enhancement algorithm based on this contrast measure can be used to perform direction contrast enhancement.

2 A new contrast measure based image enhancement algorithm in the DCT domain

2.1 Contrast measures in the DCT domain

Several contrast measures have been proposed in the DCT domain. One contrast measure [6] is defined over frequency bands after DCT is performed on each 8*8 sub-blocks.

Let

$$D = \begin{vmatrix} d_{00} & d_{01} & d_{02} & d_{03} & d_{04} & d_{05} & d_{06} & d_{07} \\ d_{10} & d_{11} & d_{12} & d_{13} & d_{14} & d_{15} & d_{16} & d_{17} \\ d_{20} & d_{21} & d_{22} & d_{23} & d_{24} & d_{25} & d_{26} & d_{27} \\ d_{30} & d_{31} & d_{32} & d_{33} & d_{34} & d_{35} & d_{36} & d_{37} \\ d_{40} & d_{41} & d_{42} & d_{43} & d_{44} & d_{45} & d_{46} & d_{47} \\ d_{50} & d_{51} & d_{52} & d_{53} & d_{54} & d_{55} & d_{56} & d_{57} \\ d_{60} & d_{61} & d_{62} & d_{63} & d_{64} & d_{65} & d_{66} & d_{67} \\ d_{70} & d_{71} & d_{72} & d_{73} & d_{74} & d_{75} & d_{76} & d_{77} \end{vmatrix} \quad (1)$$

be an 8*8 block which is composed of DCT coefficients. The contrat measure in [6] is defined for each frquency band, which is the set of DCT coefficients with approximately equal radial frequencies. About the meaning of band, please see [6]. The contrast at the n-th band ($n \geq 1$) is defined as [6]

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

where

$$E_t = \frac{\sum_{k+l=t} |d_{k,l}|}{N} \qquad (3)$$

is the average amplitude over a spectral band [6]. Here

$$N = \begin{cases} t+1 & t < 8 \\ 14 - t + 1 & t \geq 8 \end{cases} \qquad (4)$$

The contrast measure in [6] can't be used to measure the direction contrast of the images. For this, another contrast measure in [4] is proposed. In [4], the contrast measure is defined over each coefficient in the 8*8 matrix after DCT is performed on each 8*8 sub-block. The contrast at each coefficient in the n-th band is defined as [4]

$$C_{i,j} = \frac{d_{i,j}}{\sum_{k=0}^{n-1} E_k} \qquad (5)$$

2.2 A new image enhancement algorithm in the DCT domain

Our image enhancement algorithm is based on the contrast measure defined in (5). Let the contrast of each DCT coefficient from the original image block and the contrast of the corresponding DCT coefficient from the enhanced image block have the following relationship:

$$\lambda_{ij} \frac{d_{ij}}{\sum_{k+l<i+j} d_{kl}} = \frac{d'_{ij}}{\sum_{k+l<i+j} d'_{kl}} \qquad (6)$$

where d'_{ij} is the DCT coefficient of the enhanced image block, λ_{ij} is the enhancement factor. Obviously, when $\lambda_{ij}>1$, the image will be enhanced. The DCT coefficients after contrast enhancement can be obtained by

$$d'_{ij} = \frac{\lambda_{ij} d_{ij} \sum_{k+l<i+j} d'_{k,l}}{\sum_{k+l<i+j} d_{kl}} \qquad (7)$$

The algorithm can be implemented iteratively starting with $d'_{00} = d_{00}$.

For convenience, let

$$\Lambda = \begin{bmatrix} \lambda_{00} & \lambda_{01} & \lambda_{02} & \lambda_{03} & \lambda_{04} & \lambda_{05} & \lambda_{06} & \lambda_{07} \\ \lambda_{10} & \lambda_{11} & \lambda_{12} & \lambda_{13} & \lambda_{14} & \lambda_{15} & \lambda_{16} & \lambda_{17} \\ \lambda_{20} & \lambda_{21} & \lambda_{22} & \lambda_{23} & \lambda_{24} & \lambda_{25} & \lambda_{26} & \lambda_{27} \\ \lambda_{30} & \lambda_{31} & \lambda_{32} & \lambda_{33} & \lambda_{34} & \lambda_{35} & \lambda_{36} & \lambda_{37} \\ \lambda_{40} & \lambda_{41} & \lambda_{42} & \lambda_{43} & \lambda_{44} & \lambda_{45} & \lambda_{46} & \lambda_{47} \\ \lambda_{50} & \lambda_{51} & \lambda_{52} & \lambda_{53} & \lambda_{54} & \lambda_{55} & \lambda_{56} & \lambda_{57} \\ \lambda_{60} & \lambda_{61} & \lambda_{62} & \lambda_{63} & \lambda_{64} & \lambda_{65} & \lambda_{66} & \lambda_{67} \\ \lambda_{70} & \lambda_{71} & \lambda_{72} & \lambda_{73} & \lambda_{74} & \lambda_{75} & \lambda_{76} & \lambda_{77} \end{bmatrix} \qquad (8)$$

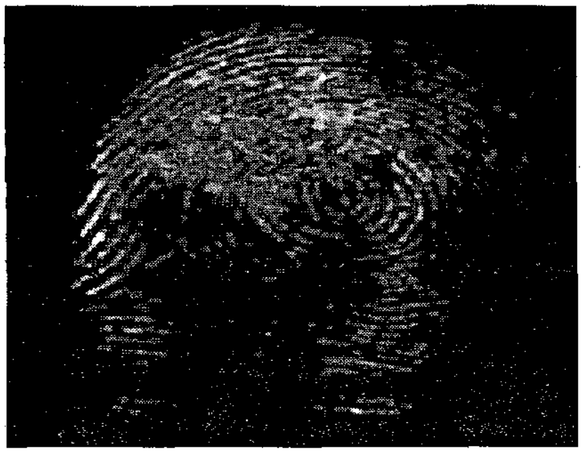
we call it enhancement factor matrix.

One of the advantages of the proposed method is that we can choose the enhancement factor matrix according to the requirement of the applications. The simple way to choose the enhancement factors is to set all of the enhancement factors to be the same value. In this case, the image will be enhanced uniformly in all of the frequencies and directions.

Besides the uniform enhancement, sometimes we need to enhance the image non-uniformly. This kind of applications include the interlaced video enhancement. We know that, many movies are compressed in MPEG format but shown on TV monitor. In these applications, the MPEG compressed movie either has the interlaced format or will be converted into interlaced video before it is shown on the TV monitor. If we enhance the MPEG movie uniformly in all of the frequencies, there will be a flickering problem [5] when the enhancement is performed. The flickering problem is mainly caused by the enhancement of the vertical direction contrast of the image [5]. Thus, the flickering problem can be solved by enhancing the horizontal direction contrast but keeping the vertical direction contrast of the image unchanged. For the algorithm developed in this paper, we can set the enhancement factor matrix as follows to realize this aim.

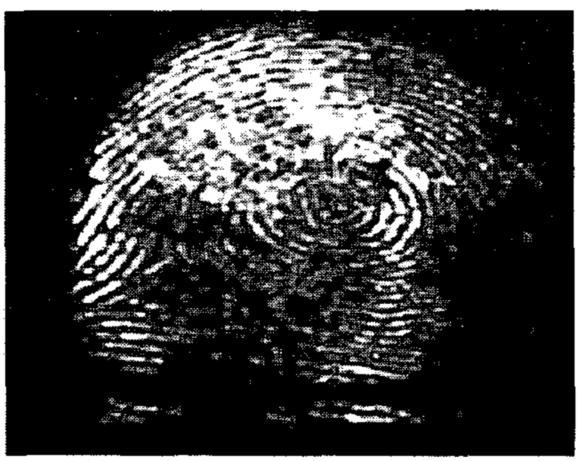
$$\Lambda = \begin{bmatrix} \lambda_{00} & \lambda_{01} & \lambda_{02} & \lambda_{03} & \lambda_{04} & \lambda_{05} & \lambda_{06} & \lambda_{07} \\ 1 & \lambda_{11} & \lambda_{12} & \lambda_{13} & \lambda_{14} & \lambda_{15} & \lambda_{16} & \lambda_{17} \\ 1 & 1 & \lambda_{22} & \lambda_{23} & \lambda_{24} & \lambda_{25} & \lambda_{26} & \lambda_{27} \\ 1 & 1 & 1 & \lambda_{33} & \lambda_{34} & \lambda_{35} & \lambda_{36} & \lambda_{37} \\ 1 & 1 & 1 & 1 & \lambda_{44} & \lambda_{45} & \lambda_{46} & \lambda_{47} \\ 1 & 1 & 1 & 1 & 1 & \lambda_{55} & \lambda_{56} & \lambda_{57} \\ 1 & 1 & 1 & 1 & 1 & 1 & \lambda_{66} & \lambda_{67} \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & \lambda_{77} \end{bmatrix} \qquad (9)$$

where $\lambda_{ij}(i \leq j)$ can be set to be the same value. Besides the application to the interlaced video enhancement, direction contrast enhancement can also be applied to many other cases. We will discuss one of the applications in the part of experiments.



(a) The decompressed image

(b) The enhanced image using the proposed method (all of the enhanced factors are 1.8)



(c) The enhanced image using histogram equalization

Figure 1. Uniform enhancement experimental results

With the method proposed above, we can enhance the JPEG compressed images in the decompression stage. For a JPEG image, we first perform some entropy decoding and inverse quantization to obtain the DCT coefficients, then we use equation (6) to modify the coefficients. After all of the DCT coefficients have been modified, inverse DCT is applied to obtain the reconstructed image for display.

3 Experimental results

In order to show the effectiveness of our algorithm, a small database of images was set up for the purpose of experiments. This database collected 100 blurred images. A graphical user interface was designed to enable the change of contrast factors and the target images for enhancement. Different kinds of blurred images were collected into a database of images. This database can be in any size and can be updated at any time without doing any revision to the program. Through the buttons, popup menus and sliders, the graphical user interface hides the details and complexity of the algorithm and program from the end users. The end user can perform any experiment without the necessity to know any detail inside. The graphical interface makes this system fool proof. It can be operated by any non-image-processing-expert.

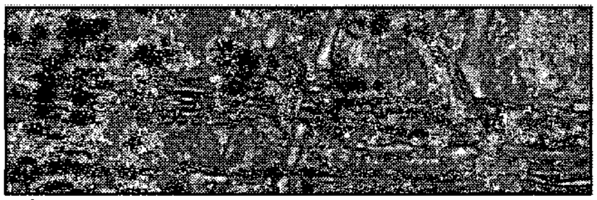
Two experiments have been performed. The first experiment used uniform enhancement. The second experiment used non-uniform enhancement.

In the first experiment, the method proposed in section 2 was evaluated against histogram equalization [3] with different blurred images respectively. Figure 1 shows one example. When compared with the original image (the decompressed image without enhancement, see Fig.1 (a)), both the histogram equalization and the proposed method produced enhanced images. However, compared with histogram equalization, the proposed method provides more details and better visual quality (see Fig.1 (b) and (c)).

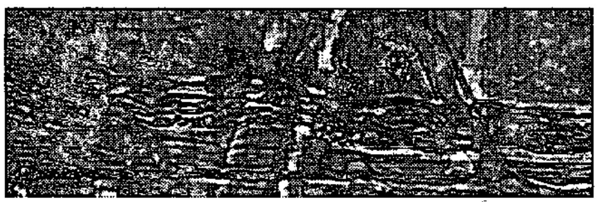
The second experiment was used to compare the effectiveness of the uniform and non-uniform enhancement algorithms. A blood vessel image was used to perform the experiments. Figure 2(a) shows the original decompressed image. In this image, because the imaging condition is not ideal, there are some unexpected vertical lines or approximately vertical lines produced in the image. The lines affect the visual effect of the vessel image. Thus, when we enhance the image, we aim to enhance the vessel contrast on the vertical direction but inhibit contrast enhancement on the horizontal direction. If the uniform enhancement algorithm is used to perform the enhancement, then the vertical line is also enhanced (see Figure 2(b)). Thus, we enhanced the image using non-uniform enhancement algorithm developed in section 2. The resultant image is shown in Figure 2 (c). The enhancement factors employed in the second experiments were

$$\lambda_{ij} = \begin{cases} 1.5 & i \geq j \\ 1.0 & i < j \end{cases} \tag{10}$$

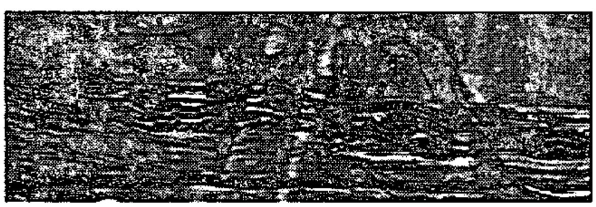
We can see that the vessel is clearly enhanced but the vertical line is kept almost the same as the original image without enhancement.



(a) Original decompressed blood vessel image



(b) Contrast enhancement in just in two directions



(c) Contrast enhancement in just in vertical direction

Figure 2. Non-uniform enhancement experimental results

4 Conclusion

In this paper, a new image enhancement algorithm in the DCT domain has been proposed for JPEG compressed images. The algorithm is especially useful for the enhancement of direction contrast.

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