EMBEDDED QUADTREE-BASED IMAGE COMPRESSION IN DCT DOMAIN

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ABSTRACT

Recent success in discrete cosine transform(DCT) image coding is mainly attributed to recognition of the importance of data organization and representation. In this paper, we proposed an embedded image coder based on quadtree set partition in DCT domain (EZDCT) which is suitable for many kinds of DCT coefficients reorganization schemes. The experimental results show that it is among the state-of-the-art DCT-based image coders when compared with the famous DCT-based image coders, such as EZDCT and MRDCT. For example, for the Barbara image, EQDCT outperforms JPEG, EZDCT and MRDCT by 3.3,1.71,1.70dB in peak-signal-to-noise ratio at 0.25bpp, respectively.

1. INTRODUCTION

Although wavelet image coding has achieved impressive success, discrete cosine transform(DCT) is still widely used in many practical image/video compression systems because of its compression performance and computational efficiency. Recent success in DCT image coding is mainly attributed to recognition of the importance of data organization and representation. Currently, there are several competitive DCT-based coders such as Xiong et al. DCT-based embedded image coding(EZDCT)[1] and Zhao et al. MRDCT[2].

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In EZDCT, Xiong et al. recognized that a DCT on 8*8 blocks of an image can be viewed as a wavelet decomposition with a uniform 8*8-subband decomposition, then they rearranged the DCT coefficients into 3-level wavelet pyramid structure and an embedded zerotree coding strategy was applied to the rearranged coefficients. The EZDCT coder has achieved higher performance compared with the classical JPEG. The DCT-based image coder called MRDCT first use rearrangement strategy of DCT coefficients which is similar to that of EZDCT, then a morphological dilation is used to represent the rearranged DCT coefficients. MRDCT outperforms EZDCT for the smooth Lena image at 0.25bpp by 0.3dB in peak signal-to-noise ratio (PSNR), however, for texture-rich image, such as the Barbara image, EZDCT outperforms MRDCT by 0.2dB at 0.5bpp.

These two existing DCT-based image coders have achieved high performance, however, some deficiencies still exist in the two state-of–the-art DCT-based image coders. One is that the magnitude decaying property across subbands which is utilized by these two image coders just only exhibits well in the pyramid subband decomposition structure. For a more general decomposition structure, the magnitude decaying property across subbands does not exist well because of the parent-child relationship being not distinct. Therefore, the DCT coefficient rearrange strategy is restricted by the sequential coding strategy in these two DCT-based image coders. The other is that MRDCT is not an embedded image coder even if it can provide high rate-distortion performance than EZDCT for the smooth Lena image.

This suggests that some embedded coding strategies that not be restricted by the arrangement strategy of DCT coefficients may be needed. Set partition based on quadtree adaptive splitting, which is used in wavelet domain successfully[3] is such a coding strategy.

In this paper, we first show that proper organization of block-based DCT coefficients can exhibit an energy-compacted characteristic. We then present an image coder utilizing this characteristic by a set partition based on quadtree splitting(EQDCT). EQDCT is an attempt to exploit the feature of DCT data that zerotree and morphological dilation do to achieve their excellent coding performance with equal or lower complexity, while at the same time improving on some of their deficiencies. A dominant feature of EQDCT is that it can supply high compression performance for smooth images and texture-rich images and is suitable for many kind of organization strategies of DCT coefficients.

The paper is organized as follows. Section 2 is the organization strategy of DCT coefficients and the exhibition of the energy-compacted property of DCT coefficients. In Section 3, the EQDCT coder design is presented. Experimental results and performance comparison are provided in Section 4. Conclusions are present in Section 5.

2 ORGANIZATION STRATEGY OF DCT COEFFICIENTS

As we know, for block-based DCT coding, an input image is first partitioned into $n*n$ blocks, where $n = 2^L, L > 0$. Then DCT is applied to each of these blocks separately. Due to typical images being most composed of smooth surfaces delimited by edge discontinuities, the DCT coefficients have some properties, such as

(1)Signal energy of smooth regions is composted mostly into dc coefficients.

(2) Due to the small compact support associated with DCT, edges can only contribute energy to a small number of ac coefficients.

There are many organization strategies of the DCT coefficients. The most efficient organization scheme must be suitable for the sequential coding scheme, that is, the organized DCT coefficients must exhibit some statistical property that can be utilized well by the sequential coding strategy.

There are two arrangement schemes following this arrangement rule based on our sequential coding scheme. One is the same as the schemes adopted in [1][2], that is, each 8*8 block can be taken as 3-scale tree of coefficients with 10 subbands composition, the same subbands for all DCT blocks are grouped and putted onto their corresponding positions. Fig.1 and Fig.2 is the demonstration of such organization scheme. The other is putting the DCT coefficients in its original position, that is, the DCT coefficients are not be rearranged. As the DCT block size is increased up to a larger size, e.g. 32*32, we found that this organization scheme also is effective for the sequential coding strategy.

Fig. 3 and Fig.4 are the DCT coefficients on the Lena image with 8*8 DCT and 32*32 DCT respectively. The gray values in Fig.4 and Fig.5 are obtained by 255-4*abs(coefficients)for better visual comparison. It is clear that the energy-compacted property is exhibited well, especially in the result corresponding to 32*32 DCT.

Fig.5 correspond to reorganized 8*8 DCT coefficients. The energy-compacted property is also displayed distinctly.

The above energy-compacted property displayed in Fig.4 and Fig.5 can be utilized to DCT-based coders in order to obtain better compression performance as set partition based on quadtree splitting did in wavelet domain.

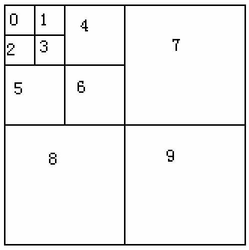

Fig.1 8*8 DCT block taken as three-scale tree with ten-subband decomposition

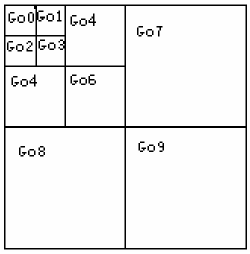

Fig.2 Reorganization of 8*8 DCT blocks into a single DCT clustering entity

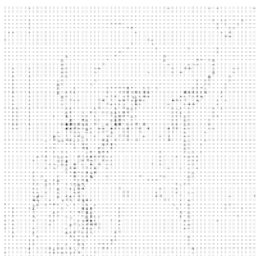

Fig.3 DCT coefficients as 8*8 blocks

Fig.4 DCT coefficients as 32*32 blocks

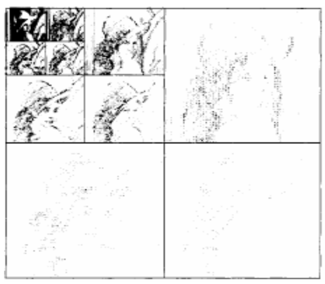

Fig.5 Reorganized 8*8 DCT coefficients into a single DCT clustering entity

3 THE PROPOSED EQDCT ALGORITHM

To utilize the energy-compacted property of DCT coefficients well, an embedded quadtree-based image coder is presented in this paper. This is similar to the quadtree coding strategy of EZBC[3] in wavelet domain, that is, the quadtree method is used to accomplished the set partitioning. We adopted the adaptive quadtree splitting method to separate the significant DCT coefficients and code every block of zero pixels into one symbol.

The proposed algorithm is outlined as follows:

1) Definition

$c(i,j)$: DCT coefficients at position(i,j).

T: quantization level.

LSP: list of the coordinates corresponding to significant coefficients.

LIB: list of the upper and bottom coefficients coordinates corresponding to the insignificant blocks.

$s_\tau(k,T)$: significance of block k with respect to quantization level T(τ is a set consists of the coefficients coordinates located in block k),that is:

$$s_\tau(k,T) = \begin{cases} 1 & \max\limits_{(i,j)\in\tau}\{|c(i,j)|\} \geq T \\ 0 & otherwise \end{cases}$$

2) Initialization

Output $n = \lfloor \log_2(\max_{(i,j)}\{|c_{i,j}|\}) \rfloor$,

Set the threshold $T = 2^n$.

Set LSP to be empty.

Set LIB to be the upper left coordinate and the bottom right coordinate of the whole transformed image.

3) Set partition sorting

For each block *k* of LIB do:

- ■ output $s_\tau(k,T)$;
- ■ if $s_\tau(k,T)$=1 then
- ◆ divide the block k into four sub-blocks
  - ● if a sub-block only have one element,
    output the symbol of the coefficient corresponding to this element.
    move its element coordinate to LSP;
  - ● else
    add the sub-block coordinate to LIB as a new node;
- ◆ remove block *k* from LIB.

4) Refine

Output the nth bit of each pixel (except the pixel stored in the last sorting pass) in LSP.

5) Updating

Replace T by T/2, and go to 3).

The coding result then is supplied to adaptive arithmetic coder[4] for more higher rate-distortion performance.

The coding procedure in EQDCT is similar to EZBC in wavelet domain. But there are some differences between them. The most one is that the quadtree set partition sorting procedure in ZEDC is applied to each subband while sorting procedure is applied to the whole images in EQDCT. So the EQDCT can suit for many kinds of data organization schemes.

4. EXPERIMENTAL RESULTS

The proposed coder was compared with the state-of-art DCT-based coders, EZDCT and MRDCT. EQDCT-I corresponds to the results of coding the rearranged DCT coefficients of 8*8 DCT coefficients, where the DCT transform/reorganization procedure is repeated on all the dc coefficients after an reorganization operation. EQDCT-II corresponds to the coding of DCT coefficients of 32*32 DCT.

Table I shows the PSNR performance comparison on the Lena image. From this table, we can see that EQDCT-I, EQDCT-II consistently outperforms JPEG by an average of 1.0dB and 1.4dB. When compared with EZDCT, EQDCT-I also performs well and gains 0.16dB at 0.125bpp. EQDCT-II outperforms all other DCT-based coder.

Table II is the PSNR performance comparison on the Barbara image. It is clear that EQDCT-I and EQDCT-II outperform EZDCT and MRDCT at low bit rate. For example, EQDCT-I outperforms JPEG, EZDCT and MRDCT by 1.82, 0.19, and 0.18dB in PSNR at 0.25bpp while EQDCT -II outperforms JPEG, EZDCT and MRDCT by 3.3, 1.71, and 1.70dB in PSNR at the same bit rate.

5. CONCLUSION

In this paper, we show that block-based DCT have an energy-compacted property firstly, then an DCT-based image coder is proposed that can suit for many kinds of organization schemes of DCT coefficients. The experimental results show that EQDCT is among the state-of-art DCT-based image coders reported in the literature.

Table I

Performance Comparison (PSNR)of Lena

bpp	0.125	0.25	0.5	1.0
EZDCT	28.50	32.27	35.98	39.60
MRDCT	29.26	32.55	35.99	39.49
JPEG	28.00	31.60	34.90	37.90
EQDCT-I	29.07	32.35	35.90	39.50
EQDCT-II	29.42	32.88	36.37	39.68

Table II

Performance Comparison (PSNR)of Barbara

bpp	0.125	0.25	0.5	1.0
EZDCT	24.07	26.83	30.82	36.10
MRDCT	24.22	26.84	30.61	35.89
JPEG	23.20	25.20	28.30	33.10
EQDCT-I	24.28	27.02	30.74	35.89
EQDCT-II	25.43	28.54	32.29	37.05

6. REFERENCES

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