A Blocking Artifacts Reduction Algorithm for Block-Transform Coding Image

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Abstract: This paper proposes a method to improve video quality on images that have blocking artifacts at block boundary. Block image transform coding suffers from blocking artifact that is a main cause of degrading video quality because of the quantization error of transform coefficients in quantization process. Filtering and DPCM for DC components have been widely used to reduce blocking artifact. Recently, lots of works focus on the technique that minimizes block effects using discontinuity of block boundaries. In this paper, image blurring in decoding stage is improved by adding compensation factor to each transformed blocks so that discontinuity of block boundaries can be decreased. The compensation factor is applied on each block without much loss of edge components.

1. Introduction

For the efficient implementation of the video image transfer, an encoding technique for the image compression is required. Various data compression algorithms have been developed using prediction, transform, and motion compensation by reducing correlation of space, frequency, and time in image data. Techniques based on block transform including the discrete cosine transform (DCT) are widely used in the international standards for image encoding such as JPEG, MPEG, H.263 and so on. Image compression using the DCT can cause discontinuity problem between blocks in the reconstructed image because the image compression basically deals with individual block in transform process. [2]

The proposed method classifies input images using quality factors and the number of DCT coefficients is selected adaptively to reduce blocking artifacts. A simple adoption of the blocking artifacts reduction algorithm may cause a problem in boundary detection resulting in image blurring. Using the characteristics of pixel values on block boundaries, the appropriate boundary value is determined so that block boundary can be distinct from block artifacts.

This paper composes of five sections. Section II describes image compression techniques that use DCT, and Section III presents a proposed algorithm. Simulation and results are discussed in Section IV and Section V concludes this paper.

2. Video Image Compression

Generally in image encoding, a transform is the block transform in which an image is subdivided into blocks and a linear, invertible transform is applied for each block. As shown in Figure 1, the encoder has the same degree of filters as the input signal has. For each subdivided blocks, the transform T is performed and the transformed coefficients y(n) are quantized and transmitted. To decode the transformed signals, inverse transform T-1 is applied. Without quantization, the transform is completely inversed. Considering energy characteristics and implementation, 8X8 or 16X16 size of block is widely used in the transform encoding[2].

2.1 DCT Algorithm

The DCT algorithm is the most popular in transform encoding for video compression since its computation is not so complicated and the decoding procedure is relatively easy compare to other methods. For these reasons, the DCT algorithm is adopted as international standards such as JPEG, MPEG, and H.261[4,5].

$$F(u) = \frac{2}{N} \sum_{x=0}^{7} f(x) \cos \frac{2(x+1)u\pi}{16} \tag{2.1}$$

The equation (2.1) shows one dimensional DCT transform. After DCT computation, most video information concentrates on low frequency data and high frequency data are ignorable.

2.2 Quantization

DCT coefficents are divided by values of the quantization table and converted into integer values

Table 1. The Quantization table

	0	1	2	3	4	5	6	7
0	16	11	10	16	24	40	51	61
1	12	12	14	19	26	58	60	55
2	14	13	16	24	40	57	69	56
3	14	17	22	29	51	87	80	62
4	18	22	37	57	68	109	103	77
5	24	35	55	64	81	104	113	92
6	49	64	78	87	103	121	120	101
7	72	92	95	98	112	100	103	99

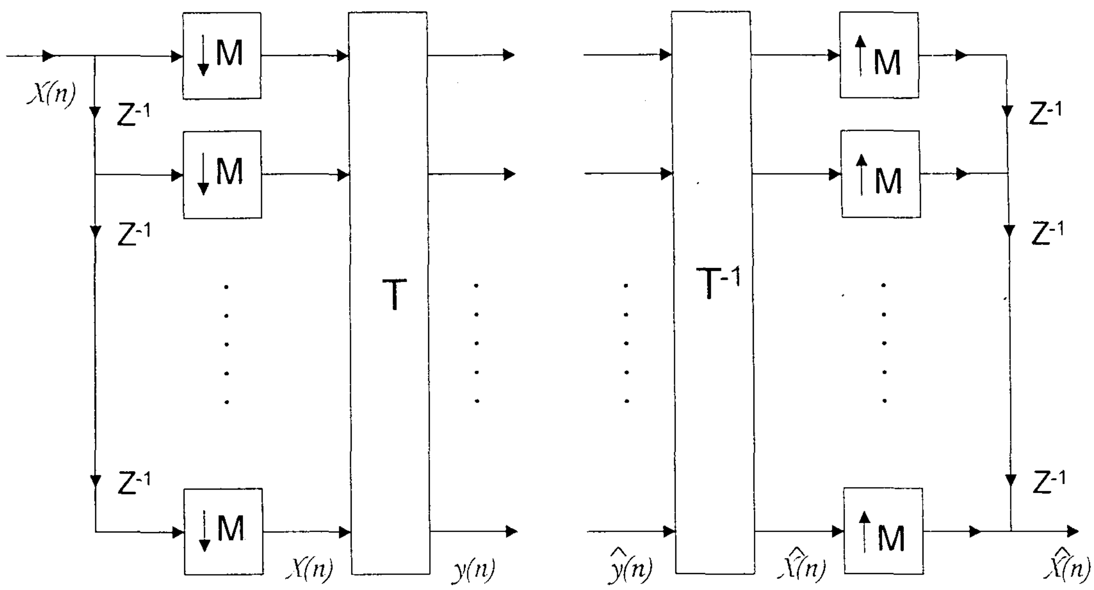

Figure 1. Architecture of Encoder/Decoder for Block-Transform Coding

Because the quantization table has large values in high frequency area, DCT coefficients in high frequency area becomes zero and this enables high compression in encoding process[4].

3. Proposed Algorithm

3.1 Blocking Artifacts

DCT coefficients consist of AC and DC components. The AC component contains part information of a block and the DC component contains characteristics of the block. Because the quantization process doesn't consider relativity between blocks, the reconstructed image in decoding process is unable to reflect relativity between blocks too. This situation gets worse as compression ratio goes high.

The quantization process that performs block by block causes blocking artifacts in encoding process. Let $f_{i,j}(x,y)$ be a pixel value of Kth block as shown in Figure 2 and $a_{i,j}(u,v)$ be a DCT coefficients at pixel (u,v). Then, $a_{i,j}(u,v)$ is expressed in the equation (3.1).

$$a_{i,j}(u,v)=\sum_{x=0}^{7}\sum_{y=0}^{7} f_{i,j}(x,y)\phi_u(x)\phi_v(y) \qquad (3.1)$$

In the equation (3.1), $\phi_u(x)$ and $\phi_v(x)$ are one dimensional DCT kernel in u and v directions respectively. $\phi_u(x)$ is given in equation (3.2) and $\phi_u(y)$ is given by replacing u and x with v and y respectively.

$$\phi_u(x)=\begin{cases}\dfrac{1}{\sqrt{N}} & u=0,\ 0\le x\le N-1\\[2ex] \dfrac{2}{\sqrt{N}}\cos\dfrac{\pi(2x+1)u}{2N} & 1\le u\le N-1,\ 0\le x\le N-1\end{cases} \qquad (3.2)$$

The $a_{i,j}(u,v)$ is quantized and encoded by the quantization table, and decoded by inverse quantization process. The $a_{Qi,j}(u,v)$ is quantized value of $a_{i,j}(u,v)$ and described in the equation (3.3).

$$a_{Qi,j}(u,v)=IR\left(\frac{a_{i,j}(u,v)}{QF\cdot Q(u,v)}\right) \qquad (3.3)$$

The QF in the equation (3.3) is the value that determines compression ratio. $Q(u,v)$ is quantization coefficients, and IR(A) is the function that rounds off A and makes it integer [1].

3.2 Definition of discontinuity and proposed algorithm

The most important factor that reduces blocking artifacts is to minimize the discontinuity at block boundary in the process of adding discontinuity value and compensation factor by inverse quantized image. The figure 2 shows the block boundary of Kth block[6,7].

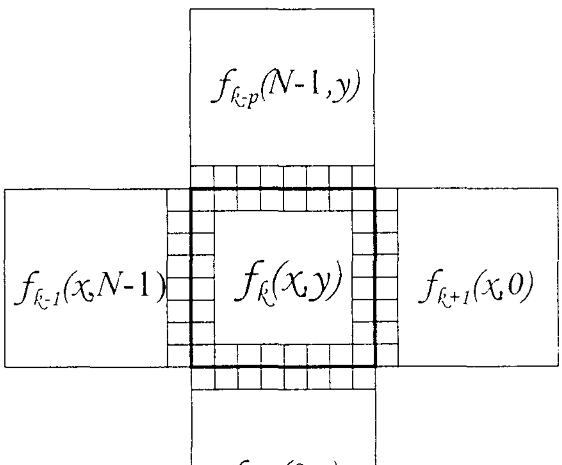

figure 2. The block boundary of Kth block

Let $f_{ij}(x,y)$ and $f_Q(x,y)$ be the brightness value of a pixel of (i,j)th block, then the block discontinuity $diff_{Qij}$ of (i,j)th block B_{ij} is given in the equation (3.4).

$$diff_{Qi,j} = \sum_{k=0}^{N-1} \begin{Bmatrix} [f_{Qi,j-1}(k,N-1) - f_{Qi,j}(k,0)]^2 \\ +[f_{Qi,j+1}(k,0) - f_{Qi,j}(k,N-1)]^2 \\ +[f_{Qi-1,j}(N-1,k) - f_{Qi,j}(0,k)]^2 \\ +[f_{Qi+1,j}(0,k) - f_{Qi,j}(N-1,k)]^2 \end{Bmatrix} \quad (3.4)$$

In the equation (3.4), $f_{Qi\pm 1,j}(x,y)$ and $f_{Qi,j\pm 1}(x,y)$ indicates four blocks neighboring the block $B_{i,j}$ and N is the number of pixels in horizontal and vertical directions.

The information loss of the block B_{ij} in quantization process, $\Delta f_{i,j}(x,y)$ is defined in the equation (3.5).

$$\Delta f_{i,j}(x,y) = f_{i,j}(x,y) - f_{Qi,j}(x,y) \quad (3.5)$$

If the estimated $\Delta f_{i,j}(x,y)$ by minimization is $\Delta f'_{i,j}(x,y)$, the reconstructed image can be expressed in equation (3.6).

$$f'_{i,j}(x,y) = f_{Qi,j}(x,y) + \Delta f'_{i,j}(x,y) \quad (3.6)$$

The difference between the original image and the reconstructed image in the plain area can be considered as a quantization error. But the difference in the non-uniformed area more depends on the pixel differences of the original image than quantization error. The weight λ compensates the differences according to the degree of uniformity of the image. The equation (3.7) describes the value that the weight applies on.

$$f'_{i,j}(x,y) = f_{Qi,j}(x,y) + \lambda_k \Delta f'_{i,j}(x,y) \quad (3.7)$$

4. Simulation and Results

For simulation in this paper, 256X256 size of the still Lenna image. The proposed algorithm is applied in proportion to the number of efficiency_pixel that indicates the compression ratio since blocking artifacts depend on the compression ratio.

Table 2. simulation results of proposed algorithm

λ	PSNR(dB)		
	efficiency_pixel 10	efficiency_pixel 6	efficiency_pixel 3
1	27.82	27.14	25.56
0.9	27.71	27.01	25.34
0.8	27.56	26.79	25.12
0.7	27.36	26.54	25.04
0.6	27.12	26.28	24.87
0.5	26.86	25.97	24.73
0.4	26.58	25.73	24.62
0.3	26.31	25.48	24.54
0.2	26.15	25.23	24.46

Simulation results are expressed in PSNR for objective value and λ is found to improve the PSNR value. The table 3 shows simulation results of proposed algorithm and existing methods.

Table 3. simulation results of proposed algorithm and existing methods

Algorithm	PSNR(dB)
Quantized image	28.34
Low-pass filter	27.22
Proposed algorithm	27.79

5. Conclusion

In this paper, the discontinuity of the block is defined and the weight λ is applied according to quantization error to minimize blocking artifacts. To minimize the block discontinuity, the loss information is estimated and the proper compensation factor is evaluated. As mentioned in simulation results, the PSNR value goes lower with less efficiency_pixel. This result expects decrement of data on VLC later. This is because only block boundary is considered and edge values of the original image is not considered. A method that considers edge values of the image is left for future works.

References

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Figure 3. Original Lenna image (256X256)

Figure 4. Efficiency_pixel 10 Lenna image (256X256)

Figure 5. Efficiency_pixel 6 Lenna image (256X256)

Figure 6. Efficiency_pixel 3 Lenna image (256X256)