Implementing a new algorithm to reduce block artifacts in DCT coded images

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Abstract- Image compression is required to reduce the number of bits needed to store or transmit images without any appreciable loss of information or quality. Image compression is of great importance in digital image processing because of its wide applications. In particular, the discrete cosine transform (DCT) is the basis for most image-coding standard. It represents an image as a sum of sinusoids of varying magnitudes and frequencies. DCT is often used in image compression applications since most of the visually significant information about the image is concentrated in just a few coefficients of the DCT. However, at low bit rates, there constructed images at the receiver end generally suffer from visually annoying block artifacts which is the boundaries between adjacent image blocks visible at low bit rates resulting from a coarse quantization. In this paper, a block effect reduction algorithm in DCT domain is proposed to reduce block artifacts as many as possible, while preserving edge information. A visibility function of block artifacts is proposed based on the activity masking and brightness masking properties of Human Visual System (HVS). No processing is needed for the blocks which visibility of the block artifacts is less than a threshold. But in smooth regions, the parameter that affects block artifacts is modified and the step blocks are replaced with linear blocks.

Index Terms- Block artifacts, Image compression, DCT coded images, Human visual systems (HVS)

I. INTRODUCTION

In a DCT compression scheme, the input image is divided into small blocks (typically 8×8), in which each block is transformed independently to convert the image elements to DCT coefficient. It is then quantized using a scalar quantizer defined by the quantization matrix. The DCT block tends to be quite sparse after quantization since the DCT coefficient concentrates most of the signal energy into a few coefficients. The quantized DCT coefficients are converted to a bit stream via variable-length encoding. The received data is decoded at the decoder end, de-quantized, and reconstructed by the inverse DCT (IDCT). At high or moderate bit rates, the DCT-coded image yields excellent result without noticeable artifacts. However, at low bit rates, it suffers from visually annoying artifacts as a result of coarse quantization. Many algorithms have been proposed for reducing these blocks artifacts. These algorithms can be classified into two major categories. 1) Using different encoding schemes such as interleaved block transform, the lapped transform, and the combined transform. 2) Post-process the constructed images. This strategy is of practical interest since it only requires the decoded image, and hence is fully compatible with the image coding standards. Luo [1] proposed 2-D DCT method to remove blocking artifacts. Although this method is simple but it cannot retain the high-frequency information of image. Zeng [2] proposed a DCT domain method for blocking effect reduction by applying a zero mask to the DCT coefficient of some shifted image blocks. However, the loss of edge information caused by the zero masking schemes can be noticed easily.

In this paper, a new algorithm is implemented for blind measuring the block artifacts in DCT domain. This measurement is based on characteristics of the Human Visual System (HVS) to achieve satisfied visual results. Experimental results show that the proposed method is robust and consistent with human perception. It yields excellent block artifacts suppression while maintaining good image quality

II. THE BLOCK ARTIFACT REDUCTION FILTER

In this paper, a novel and efficient algorithm is implemented for blind measuring the block artifacts in DCT domain. Based on the local visibility measure, the block artifacts at each edge in the original image are divided into three categories. In the three types of block edges different processing algorithm are applied in order to reduce the block artifacts and also preserve the integrity of the original image. The blocks for which the visibility function is less than the threshold do not need any processing. Otherwise for smooth regions, the parameter that affects block artifacts is modified by replacing step blocks with linear blocks. The proposed scheme for reducing block artifacts yields excellent block artifacts suppression and also maintains good image quality.

A. Model for Block Artifacts

Consider two horizontally adjacent 8×8 blocks a and b with visible block artifacts between them. A new shifted block c is composed of the right half of block a and the left half of block b. The block artifacts between block a and block b can be modeled as a step function. Define a step block‘s as follows:

$$s(i,j) = \begin{cases} -\frac{1}{8} & i = 0,1,2,3,4,5,6,7\ ;\ j = 0,1,2,3 \\ \frac{1}{8} & i = 0,1,2,3,4,5,6,7\ ;\ j = 4,5,6,7 \end{cases}$$

Therefore, the model of c can be shown as:

$$c(i, j) = \beta s(i, j) - \mu - r(i, j), \qquad i, j = 0,1,2,3,4,5,6,7$$

where μ is the average value of the block c which indicates the local background brightness while the local activity around the block edge is describe by the residual block r. The larger the value of |β|, the blocking effect is more serious, provided that local activity and the background brightness remain same

B. HVS-based Visible Function of Block Artifacts

The mean squared difference of slopes (MSDS) is used to measure the block artifacts. The MSDS of block c is defined as follows:

$$\text{MSDS} = \sum_{i=0}^{7}\left[\frac{\{c(m,2) - 3c(m,3) + 3c(m,4) - c(m,5)\}}{2}\right]^2$$

Here c(i, j) is the luminance value of the pixel(i, j) of the block c. The masking of background activity and brightness are two well-studied properties of the HVS which are highly relevant to the perception of block artifacts.

C. Activity Masking

The visibility of the block artifacts of block c is known to a monotonously decreasing function of the activity. A horizontal masking function M_h for block artifacts is defined as follows:

$$M_h = (1 + A_v + \propto A_h)^{-1}$$

The horizontal activity A_h and the vertical activity A_v were defined as follow:

$$A_h = \sum_{u=0}^{7} u \sum_{v=0}^{7} W(u, v)\,|T(u, v)|$$

$$A_v = \sum_{v=0}^{7} v \sum_{u=0}^{7} W(u, v)\,|T(u, v)|$$

where *T(u, v)* is the amplitude of the DCT coefficients of the block c. *W(u, v)* are the weighting factors dependent on the visual sensitivity of the human eye to spatial frequencies. Similarly, for the vertical block artifacts, we can define the vertical block artifacts masking function M_v.

D. Brightness Masking

The visibility of block artifacts also depends on the local background luminance. The visibility of the block artifacts is known to a monotonously decreasing function of the local background luminance. A brightness masking function M_l is defined as follows:

$$M_l = \left(1 + \left(\frac{b}{b_0}\right)^r\right)^{-1}$$

where b_o and r are constants, $b_o = 150$, $r = 2$.
b is the average luminance value of the block c.

E. The visibility Function of Block Artifacts

From above description, we define a horizontal visibility function of block artifacts of the block c, as follows:

$$n_h = K \times MSDS \times M_h \times M_l$$

where K is constant, in this project K = 2000, α = 0.8.

F. Edge detection

For block artifacts in horizontal and vertical direction have no difference in essence, the de-blocking methods for horizontal direction artifacts is also suitable for vertical direction ones. Given a DCT block edge, if its measured visibility n_h falls below a certain threshold, no further process needs to be applied to the block edge. Otherwise, it is considered that reduction of block artifacts will be necessary. The threshold is determined experimentally. At this time, the edges of block c should be detected to avoid blurring information-bearing edges in the image. In this project, a new edge-detection method is introduced. When the shifted block c satisfies the following condition:

1. $|c(i, j) - c(i, j + 1)| <= |c(i,4) - c(i,5)|, \quad i = 0,1,2\ldots..,7 \quad j = 0,1,2\ldots..,6$
2. $|c(i,4) - c(i,5)| <= 2QP, \quad i = 0,1,2\ldots..,7$

Then it is deemed that there are no edges in shifted block c. Condition 1 assures that the difference between inner pixels cannot exceed the difference between the boundary pixels of block a and b. Condition 2 avoids that the edges just appear on the boundary of block a and b. QP is quantization parameter. In general QP is 16.

F. Reduction of Block Artifacts for Smooth Region

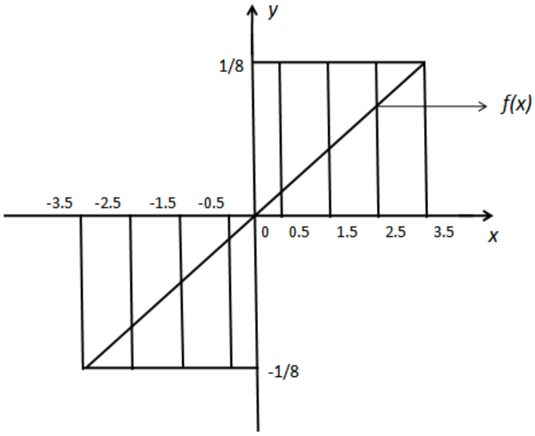


Figure 1: Linear function block

In order to reduce block artifacts, we replace the 2-D step blocks with a 2-D linear block *l* in the shifted block shown in Figure 1. The linear block *l* can be obtained as:

$$l = [f(-3.5), f(-2.5), f(-1.5), f(-0.5), f(0.5), f(1,5), f(2.5), f(3.5)]$$

where $f(x) = x/28$;

We can see from the equation in above sections, that β affects the block artifacts, which is relevant to C(0,1), C(0,3) , C(0,5) and C(0,7). If we directly use linear function to replace step function, these coefficients will be modified. However in this case, this change only uses the information of the shifted block c, and the left block a and the right block b is ignored, which can introduce the new block artifacts. For this reason, we use the information of the left block a and the right block c to modify the value of C(0,1), C(0,3), C(0,5) and C(0,7). In the end, the linear function is applied to replace step function to reduce block artifacts. So in this case, the information of block a and b can be sufficiently utilized.

$$E(0, i) = 0.5C(0,i) + 0.25(A(0, i) + B(0, i)), i = 1,3,5,7$$

$$\beta_1 = L(0,1)E(0,1) + L(0,3)E(0,3) + L(0,5)E(0,5) + L(0,7)E(0,7),$$

where A, B, C, L is the2-D DCT transform of a, b, c and l. Because β_1 contains the change that easily produces the block artifacts. So the value of C is not changed. Otherwise the new block artifacts will appear. Then c in DCT domain is updated as

$$C_1(0, j) = C(0,j) + \beta_1(L(0,j) - S(0,j))$$

$$C_1(i,j) = C(i,j), \qquad i>0, j= 0,1,2\ldots,7$$

G. Post-filtering

The post-filtering is performed in spatial domain in the updated block c. We define three levels of local visibility of artifacts, which determine three modes of luminance filtering. One-dimensional adaptive low-pass filtering is executed first in the horizontal direction, followed by vertical filtering. The filtering is applied in raster-scan order through the whole frame. The purpose of the first two modes of our artifact reduction method is to reduce high-frequency components of a block grid.

The **first filtering mode** is used against highly visible blocks, characterized by local maximum amplitude of a luminance discontinuity.

$$\mathrm{MAX}(D1, D2, D3, D4) < |Y3-Y4| < T_{lum}$$

where, $D1 = |Y1-Y2|$; $D2 = |Y3-Y2|$; $D3 = |Y4-Y5|$;
$D4 = |Y5-Y6|$

Y_i are the pixel values of the block c.

The threshold T_{lum} is calculated experimentally.

The filtering in this mode is the strongest:

$$Y3' = (Y2 + Y3 + Y4)/3,$$
$$Y4' = (Y3 + Y4 + Y5)/3,$$

where Y3’, Y4’ is output luminance pixel values.

If $|Y1-Y4| < T_{lum}/2$, then we can filter pixels Y1, Y2, which are not adjusted to the block edge:

$$Y2' = (Y1 + Y2 + Y4)/3,$$
$$Y1' = (3 \times Y1 + Y4)/4,$$

The similar condition is estimated for the other side of the block edge.

If $|Y6-Y3| < T_{lum}/2$, then we can filter pixels Y5, Y6:

$$Y5' = (Y6 + Y5 + Y3)/3,$$
$$Y6' = (3 \times Y6 + Y3)/4,$$

The filtering of Y1, Y2 and Y5, Y6 pixels provides better smoothing of severe blocks**.**

The **second filtering mode** is applied to block edges with the local visibility, which is lower than in the first mode:

$$\mathrm{MAX}(D2, D3) < |Y3 - Y4| < T_{lum}$$

In this case we apply softer filtering to pixels Y3, Y4:

$$Y3' = (Y2 + 2 \times Y3 + Y4)/4,$$
$$Y4' = (Y3 + 2 \times Y4 + Y5)/4,$$

If conditions $|Y6-Y3| < T_{lum}/3$ and $|Y1-Y4| < T_{lum}/3$ are true, then pixels Y2 and Y5 are filtered as well:

$$Y2' = (Y1 + 2 \times Y2 + Y4)/4,$$
$$Y5' = (Y6 + 2 \times Y5 + Y3)/4,$$

The **third filtering mode** is applied to pixels, which are not filtered in the first two modes, or in other words, which are not located on a highly visible block grid. The goal of the third mode is to reduce residual (low-pass) components of blocks. Those artifacts exist in both smooth and textured regions; however, their visibilities are different. Although the low-pass filtering used in the third mode is less strong than in the previous modes, an image texture may be blurred, or small object edges distorted if the filtering is applied to them. To avoid smoothing of textured regions we do not filter pixels within spatially busy areas. Thus, the spatial activity around the analyzed pixel pair Y3, Y4 as well as the value of the gradient |Y3 – Y4| should below*:*

$$|Y3 - Y4| < T_{lum}/4,$$

We filter pixel Y3 in the third mode if the following conditions hold:

$$D1 < T_{lum}/5 \;\&\&\; D2 < T_{lum}/4 \;\&\&\; D3 < T_{lum}/5,$$

The pixel Y4 is filtered if the conditions below are true:

$$D2 < T_{lum}/5 \;\&\&\; D3 < T_{lum}/4 \;\&\&\; D4 < T_{lum}/5,$$

In the third mode only the luminance pixels Y3 and Y4 are processed using the soft filters:

$$Y3' = (Y1 + Y2 + 6\times Y3 + Y4 + Y5)/10,$$
$$Y4' = (Y2 + Y3 + 6\times Y4 + Y5 + Y6)/10,$$

III. PROPOSED SCHEME

A. Block artifact Reduction Filter (BARF) Algorithm

1. Convert the block artifacts image into 8×8 blocks. Take 1st and 2nd, 2nd and 3rd,…… 8×8 blocks horizontally.

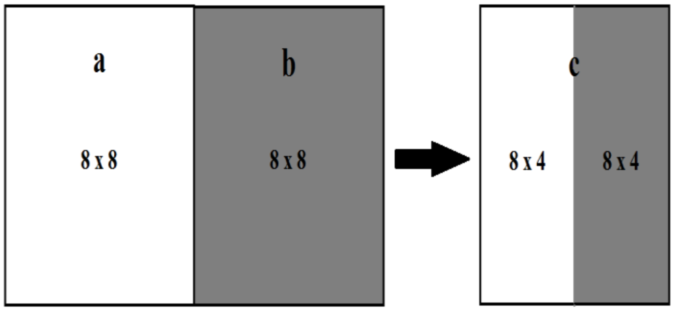


Figure 2: Illustration of the new block by combining adjacent blocks.

2. Compute mean squared difference of slopes (MSDS), which is used to measure the block artifacts.

$$\text{MSDS} = \sum_{i=0}^{7}\left[\frac{\{c(m,2) - 3c(m,3) + 3c(m,4) - c(m,5)\}}{2}\right]^2$$

3. Compute the horizontal masking function M_h for block c.

$$M_h = (1 + A_v + \propto A_h)^{-1}$$

4. Compute the brightness masking function M_l for block c.

$$M_l = \left(1 + \left(\frac{b}{b_0}\right)^{r}\right)^{-1}$$

5. The horizontal visibility function of block c, n_h is computed as

$$n_h = K \times MSDS \times M_h \times M_l$$

6. Compare the value of n_h with the threshold value. If the value n_h is less than the threshold, no further processing is required. Go to step 9. Otherwise for values greater than the threshold the image is further divided into two region – smooth region and texture or edge region.

7. For texture region goto step 9.

8. For smooth region apply linear function defined in "**Reduction of Block Artifacts for Smooth Region".**

9. Apply the post-filtering method discussed in above section to the entire image.

10. The enhanced image is obtained as output.

B. Flowchart

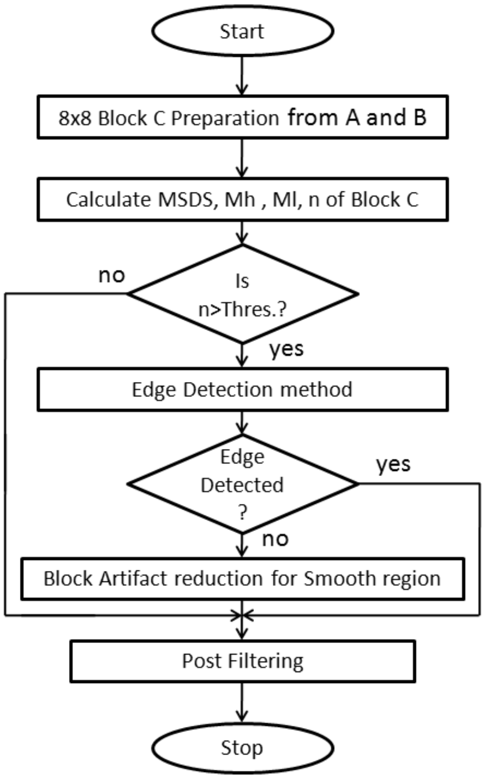


Figure 3: Flowchart of the Proposed Scheme

IV. IMPLEMENTATION AND RESULTS

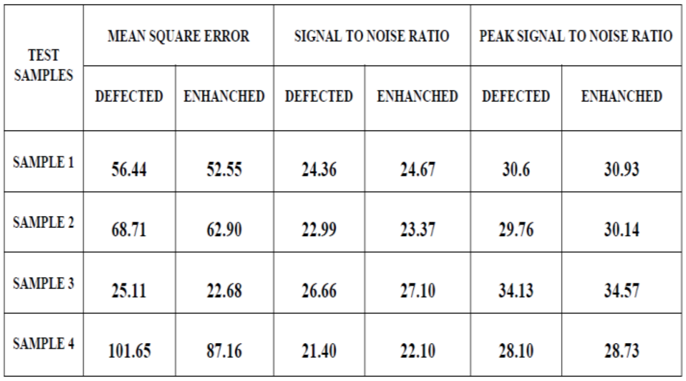
The project is implemented by following the algorithm explained in the previous section. Forward DCT of the whole image is taken by dividing the image into smaller 8×8 blocks of pixel and applying the DCT on each block. This increases the efficiency and consumes less time to compute the forward DCT. The DCT coefficients are quantized and then encoded. At the decoder end, the received data is decoded, de-quantized and reconstructed by the inverse DCT (IDCT). At low bit rates, the reconstructed image suffer from blocking artifacts. To reduce this effect, the proposed Block Artifacts Reduction Filter (BARF) is used and the enhanced image is obtained as output.

The codes for the Block Artifacts Reduction Filter are written in C and compiled using GCC compiler under Linux platform. The enhanced images obtained after processing, using Block Artifacts Reduction Filter are shown below

Figure 4: Defected images (sample 1,2,3,4)

Figure 5: Enhanched images (sample 1,2,3,4)

Table 1: Different Parameters Related To The Images



TEST SAMPLES	MEAN SQUARE ERROR		SIGNAL TO NOISE RATIO		PEAK SIGNAL TO NOISE RATIO	
	DEFECTED	ENHANCHED	DEFECTED	ENHANCHED	DEFECTED	ENHANCHED
SAMPLE 1	56.44	52.55	24.36	24.67	30.6	30.93
SAMPLE 2	68.71	62.90	22.99	23.37	29.76	30.14
SAMPLE 3	25.11	22.68	26.66	27.10	34.13	34.57
SAMPLE 4	101.65	87.16	21.40	22.10	28.10	28.73

Above table shows the various parameters related to the images. A distortion measure is a mathematical quantity that specifies how close an approximation is to its original, using some distortion criteria.

MEAN SQUARE ERROR (MSE) is the cumulative squared error between the compressed and the original image.

SIGNAL TO NOISE RATIO (SNR) is the ratio of the average squared value of the original pixels to the mean square error. It is the measure of the quality of image. High value of SNR indicates better image quality.

PEAK SIGNAL TO NOISE RATIO (PSNR) is the maximum absolute pixel error obtained by calculating an absolute difference image of the original and the reconstructed images.

A lower value for MSE means lesser error, and as seen from the inverse relation between MSE and PSNR, this translates to a high value of PSNR. Logically, a higher value of SNR and PSNR is good because it means that the ratio of signal to noise is higher. So if we find a compression scheme having a lower MSE and a high PSNR, we can recognize that the image is a better one.

V. CONCLUSIONS

A de-blocking algorithm in DCT domain is proposed, which can significantly reduce block artifacts while preserving edge and texture information as much as possible. The characteristic of Human visual system (HVS) is sufficiently utilized in this project. Different de-blocking methods are applied to different regions. The proposed algorithm has been applied to a set of sample images as shown in Figure 4. A better quality output is obtained as we can see from the images in Figure 5.

Different parameters related to the image such as Mean square error, Signal to Noise ratio and Peak Signal to Noise ratio is calculated and compared with the original images. The value clearly shows that the proposed scheme reduces block artifacts and results and image which are more visually acceptable.

The proposed algorithm can significantly reduce block artifacts while preserving edge and texture information, thus a better Image enhancement process. It can be implemented on those applications where bandwidth poses a potential bottleneck. Furthermore, any imaging application where automatic contrast enhancement and sharpening is needed, we can implement this algorithm.

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