A Novel Approach for Reduction of Blocking Effects in Low-Bit-Rate Image Compression

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***Abstract*— In this letter we propose a new approach for removing blocking artifacts in reconstructed block-encoded images. The key of the approach is using piecewise similarity within different parts of the image as *a priori* to give reasonable modifications to the block boundary pixels. This makes our approach different from traditional ones, which are often developed by applying some kinds of smoothing constraints on local regions. Experimental results show that our approach well achieves enhanced decoding for JPEG-decoded images both objectively and subjectively.**

***Index Terms*— Blocking effect, image coding, image enhancement.**

I. INTRODUCTION

ONE OF THE major disadvantages of block-based image coding techniques is "blocking effect." There are two general approaches to reduce blocking effects. In the first approach, the blocking effect is dealt with at the encoding side using overlapping schemes [1], [2]. This kind of methods may lead to an increase in the bit rate or modify the encoding and decoding procedures dramatically. The second approach uses some postprocessing techniques at the decoding side. It can improve the visual quality of the reconstructed image without using any extra bits or applying any modification on the encoding or decoding procedures. Due to these advantages, most recently proposed algorithms are conducted by using the second approach [1], [3]–[7].

Generally speaking, the traditional postprocessing techniques, whether they are applied in spatial or transform domain, are implemented by applying some smoothing constraints on the local regions. In this letter, we propose a fundamentally different approach which breaks through the traditional framework in two ways: 1) it is not necessary to apply any smoothing constraint on local regions and 2) it can make use of the information of remote regions.

II. BLOCKING EFFECT REDUCTION ALGORITHM

Suppose the image block size is fixed to be $N \times N$. Our algorithm is first applied horizontally to recover

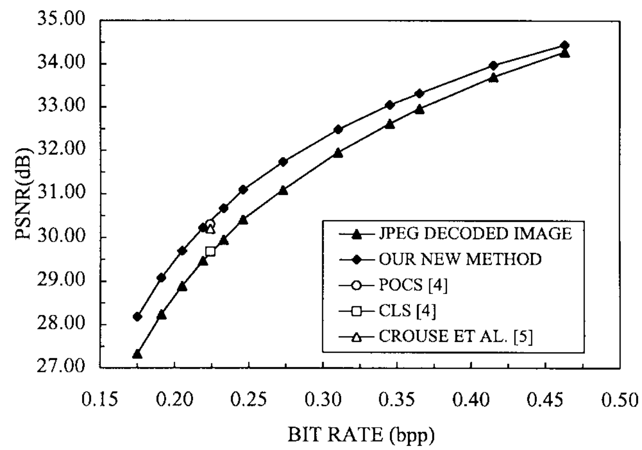

Fig. 1. Postprocessing results for JPEG-decoded image. "Lena," 512 × 512, 8 bit/pixel.

vertical boundaries. Let $\boldsymbol{x} = (x_{-N/2}, x_{-N/2+1}, \cdots, x_{-1}, x_0, \cdots, x_{N/2-2}, x_{N/2-1})$ be the vector of the pixel values across the boundary of two blocks in the blocky image, where $x_{-N/2}, x_{-N/2+1}, \cdots, x_{-1}$ and $x_0, \cdots, x_{N/2-2}, x_{N/2-1}$ are two groups of pixels in the same line of the left and right blocks, respectively. The real block boundary is between x_{-1} and x_0. Let $\boldsymbol{y} = (y_{-N/2}, y_{-N/2+1}, \cdots, y_{-1}, y_0, \cdots, y_{N/2-2}, y_{N/2-1})$ be the vector of a line of pixels within one block. Since all the pixels in $\boldsymbol{y}$ are in the same block, we assume $\boldsymbol{y}$ is of good continuity and use the continuity of $\boldsymbol{y}$ to recover the discontinuity of $\boldsymbol{x}$. For a certain $\boldsymbol{x}$, there exist many possible $\boldsymbol{y}$'s in the whole image, but we choose only one from them. First, a candidate $\boldsymbol{y}$ should not be very far away from $\boldsymbol{x}$. We restrict it to be within an m pixel wide and n pixel high rectangle region centered about the middle point of $\boldsymbol{x}$. The criterion for the selection of $\boldsymbol{y}$ from these candidate $\boldsymbol{y}$'s is how well it can match $\boldsymbol{x}$ through a matching function f. In other words, it should be similar to $\boldsymbol{x}$. This is what we have mentioned "piecewise similarity." We use a one-order linear function $f(y) = a_0 + a_1 y$ as the matching function and use the weighted mean-square error (WMSE) to evaluate the matching result

$$E = \sum_{i=-N/2}^{N/2-1} w_i[x_i - f(y_i)]^2 = \sum_{i=-N/2}^{N/2-1} w_i[x_i - (a_0 + a_1 y_i)]^2 \quad (1)$$

where the weight vector $\boldsymbol{w} = (w_{-N/2}, w_{-N/2+1}, \cdots, w_{-1}, w_0, \cdots, w_{N/2-2}, w_{N/2-1})$ satisfies the following conditions:

$$0 \leq w_i \leq 1, \qquad i = -N/2, \cdots, N/2-1 \quad (2)$$

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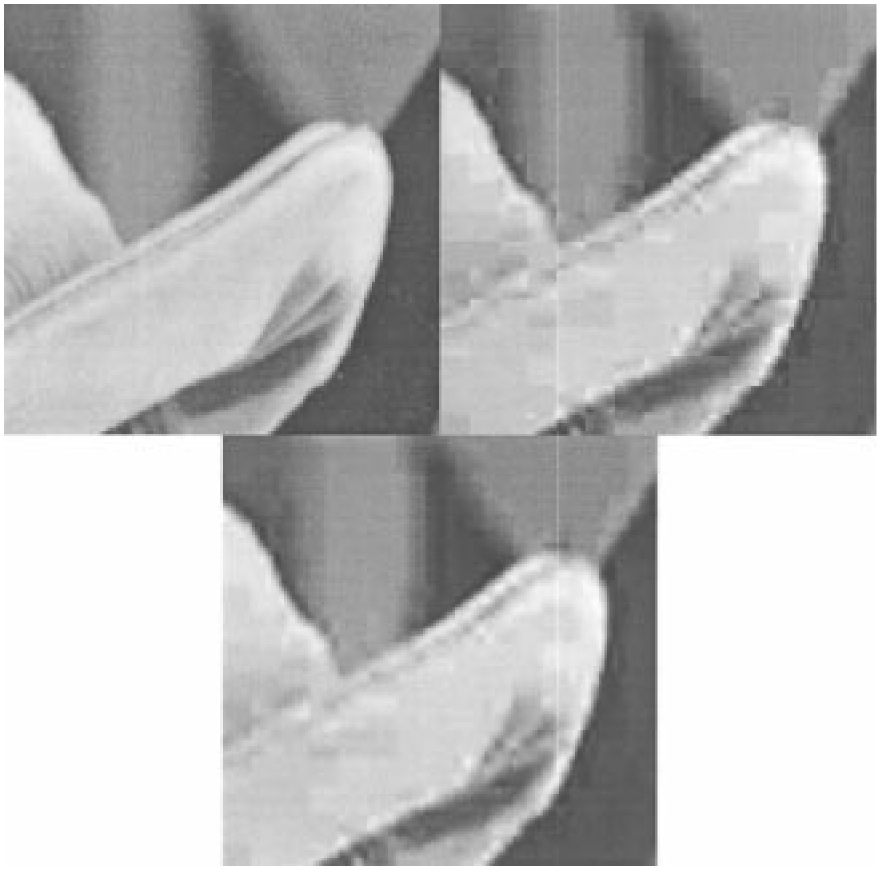

Fig. 2. Illustration of postprocessing result for hat region of "Lena." Top left: original image. Top right: JPEG-decoded image. Bottom: postprocessed image.

$$w_{-k} = w_{k-1}, \qquad k = 1, \cdots, N/2 \tag{3}$$

$$\sum_{i=-N/2}^{N/2-1} w_i = 1. \tag{4}$$

By solving the equations $\partial E/\partial a_0 = 0$ and $\partial E/\partial a_1 = 0$, we can obtain the parameters a_0 and a_1

$$\begin{cases} a_1 = \dfrac{\sum\limits_{i=-N/2}^{N/2-1} w_i x_i \cdot \sum\limits_{i=-N/2}^{N/2-1} w_i y_i - \sum\limits_{i=-N/2}^{N/2-1} w_i x_i y_i}{\left(\sum\limits_{i=-N/2}^{N/2-1} w_i y_i\right)^2 - \sum\limits_{i=-N/2}^{N/2-1} w_i y_i^2} \\ a_0 = \sum_{i=-N/2}^{N/2-1} w_i x_i - a_1 \cdot \sum_{i=-N/2}^{N/2-1} w_i y_i. \end{cases} \tag{5}$$

Each candidate $\boldsymbol{y}$ will result in an E but only the one with the minimal E is our ultimate choice. The selected $\boldsymbol{y}$, together with $\boldsymbol{x}$, is used to generate the recovered vector $\boldsymbol{x}' = (x'_{-N/2}, x'_{-N/2+1}, \cdots, x'_{-1}, x'_0, \cdots, x'_{N/2-2}, x'_{N/2-1})$. Each x'_i is a linear combination of x_i and $f(y_i)$

$$x'_i = [1 - c_i \cdot g(E)] \cdot x_i + c_i \cdot g(E) \cdot f(y_i) \tag{6}$$

where the vector $c = (c_{-N/2}, c_{-N/2+1}, \cdots, c_{-1}, c_0, \cdots, c_{N/2-2}, c_{N/2-1})$ is selected so that

$$0 \le c_i \le 1, \qquad (i = -N/2, \cdots, N/2 - 1) \tag{7}$$

$$c_{-k} = c_{k-1}, \qquad (k = 1, \cdots, N/2). \tag{8}$$

$g(E)$ is defined as

$$g(E) = \begin{cases} 1 - \left(\dfrac{1 - T_C}{T_E}\right) \cdot E, & \text{if } 0 \le E \le T_E \\ 0, & \text{otherwise} \end{cases} \tag{9}$$

where T_C and T_E are two parameters used to control the shape of $g(E)$. The goal of using $\boldsymbol{c}$ and $g(E)$ is to provide a tradeoff between modification and maintenance of $\boldsymbol{x}$. c should be selected so that the closer the pixel to the block boundary, the more it is modified. $g(E)$ is selected so that the better $\boldsymbol{y}$ can match $\boldsymbol{x}$, the more $\boldsymbol{x}$ is modified. In very few special cases where we can not find a $\boldsymbol{y}$ that can match $\boldsymbol{x}$ well, i.e., all $E > T_E$, we just use a simple method to smooth x_{-1} and x_0

$$x'_{-1} = (1 - p) \cdot x_{-1} + p \cdot x_0 \tag{10}$$

$$x'_0 = p \cdot x_{-1} + (1 - p) \cdot x_0 \tag{11}$$

where $0 < p < 1$ is employed to determine how much the pixel values are smoothed. Our algorithm is first applied to the vertical block boundaries of every line. Then it is applied to the horizontal block boundaries using the same way. The corner of each block is processed as the average of these two procedures.

III. Experimental Results

We use several 8-bit/pixel grayscale images to test our algorithm. The test images are first coded using JPEG standard at different bit rates, where the JPEG program is from the version 6 of the Independent JPEG Group (IJP). The JPEG decoded images are then subject to our blocking effect reduction

TABLE I
POST-PROCESSING RESULTS OF "LENA" 512 × 512, 8 BITS/PIXEL

Bit Rate (bpp)	PSNR (dB) of JPEG Decoded Image	PSNR (dB) of Post-Processed Image
0.175	27.33	28.18
0.219	29.47	30.22
0.246	30.41	31.09
0.310	31.95	32.48
0.365	32.96	33.33
0.415	33.70	33.97

algorithm. In our approach, the following control parameters are chosen:

$$N = 8,\ m = 64,\ n = 32,\ T_E = 200,\ T_C = 0.75,\ p = 0.3$$
$$\boldsymbol{w} = (0.2, 0.15, 0.1, 0.05, 0.05, 0.1, 0.15, 0.2)$$
$$\boldsymbol{c} = (0.25, 0.55, 0.65, 1, 1, 0.65, 0.55, 0.25).$$

The same set of parameters is applied to all of the test images coded at all tested bit rates.

To make our algorithm easily compared with other approaches, the experimental results given in this letter are under the following conditions: 1) the test image is 512×512 image "Lena;" 2) peak signal-to-noise ratio (PSNR) is used as the objective standard to evaluate the postprocessing results; and 3) the test image is encoded and then decoded using JPEG standard at a relatively large range of bit rates ranging from about 0.15–0.45 bit/pixel. The decoding and postprocessing results are shown in Table I and Fig. 1. By using our blocking effect reduction algorithm, PSNR's are improved by a magnitude of 0.2–0.85 dB. Our algorithm achieves relatively good results among those obtained by other approaches such as POCS [4], CLS [4], and Crouse *et al.*'s method [5], which are also shown in Fig. 1. Fig. 2 gives subjective illustrations of the decoding and postprocessing results of the enlarged hat region of "Lena." The postprocessed image appears to have enhanced quality from the JPEG decoded image.

IV. CONCLUSIONS

In this letter we introduce a new approach to reduce blocking artifacts from block-coded images. Different from traditional approaches, our algorithm is implemented by employing a special kind of information redundancy—piecewise similarity within natural images. Experiments on JPEG-decoded images indicate that both PSNR and visual quality are improved.

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