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Hao-Song Kong   Yao Nie   Anthony Vetro
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TR-2004-056   June 2004

Abstract

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Proc IEEE Int’l Conference on Multimedia and Expo (ICME)

CODING ARTIFACTS REDUCTION USING EDGE MAP GUIDED ADAPTIVE AND FUZZY FILTERING

Hao-Song Kong[1], *Yao Nie*[2], *Anthony Vetro*[1], *Huifang Sun*[1] *and Kenneth E. Barner*[2]

[1]Mitsubishi Electric Research Labs
201 Broadway, Cambridge, MA 02139
hkong@merl.com, avetro@merl.com, hsun@merl.com

[2]Department of Electrical and Computer Engineering
University of Delaware, Newark DE 19716
ynie@ee.udel.edu, barner@ee.udel.edu

ABSTRACT

This paper presents a new adaptive approach for blocking and ringing artifact reduction. In order to avoid smearing of the image details, the proposed method first performs visual artifacts detection and then applies adaptive filtering to the corrupted blocks. Both visual artifacts detection and filtering are guided by an edge map which is constructed based on the local features. The fuzzy identity filter is used for image de-ringing. Since it possesses a good edge preserving property and the filtering operation is applied to the edge blocks only (smooth and textured blocks are unaltered), the proposed method shows great effectiveness of both artifacts reduction and detail preservation. Experiments demonstrate better results compared with the other methods.

1. INTRODUCTION

High compression techniques are required in many imaging and video applications. Visual artifacts are normally present in decompressed images due to coarse quantization and coefficient truncation. Blocking and ringing artifacts are the two major coding artifacts caused by high compression. Many post-processing approaches have been proposed to remove the visual artifacts either from the spatial domain or the frequency domain [1],[2],[9]. They attempt to adaptively filter each pixel in the image based on quantization parameter and neighboring information. Since these filtering methods are pixel-by-pixel operations, they inevitably introduce undesired smoothing effects to non-artifacts pixels. Recent research has proposed classification-based methods to detect the artifacts before applying the post-filtering [3],[4]. However, these methods mainly concentrate on blocking artifacts, and are less effective in removing ringing artifacts.

In this paper, we propose a new adaptive approach for both blocking and ringing artifacts removal. The proposed method is based on edge information extraction and edge preserving filtering. Since coding artifacts are observed as certain patterns to the human visual system (for example, blocking artifacts appear as block boundary discontinuities and ringing artifacts always appear around sharp edges), we first apply pattern classification techniques to identify different type of artifacts and then perform the filtering accordingly. Our strategy is as follows: 1) form an edge (variance) map based on the local statistics; 2) according to the edge map, detect the blocking artifacts and classify the coding blocks into three (smooth, edge and texture) categories [5]; 3) apply a 1-D low-pass filter to reduce the blocking artifacts and a 2-D fuzzy identity filter [6] to reduce the ringing artifacts. Since the fuzzy identity filter is applied to the edge blocks only (other types of blocks are unaltered) and it possesses a good edge preserving property, the filtered images look sharp and clean.

2. THE PROPOSED APPROACH

Figure 1 shows the system diagram of the proposed post-filtering scheme. The system consists of the following modules: feature extraction, blocking artifacts detection and de-blocking, pixel/block classification and de-ringing.

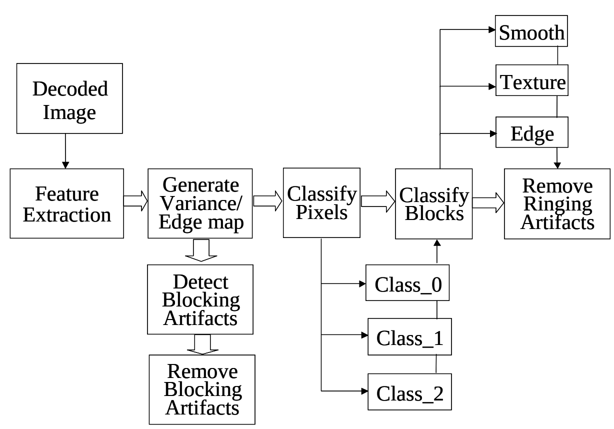

Figure 1. Proposed post-filtering scheme.

2.1 Local feature extraction

Since the local variance can effectively characterize the local feature of the image, the variance within a 3x3 window centered at each pixel is calculated. The local variance values of all the pixels form a variance (edge) map for the entire image.

2.2 Blocking artifact detection and de-blocking

The blocking artifact detection is performed on the non-overlapping 8×8 blocks in the edge map obtained in the previous step. For each block, only the top and left boundaries need to be checked as shown in Figure 2. The criterion for deciding that blocking artifacts are present at the corresponding boundary is

$$\left|\sum_{i=1}^{6} sign\ (*_i - \bullet_i)\right| \geq 5,$$

where $*_i$ and $\bullet_i$ ($i=1,2,\ldots 6$) represent the local variance values of 6 boundary pixels and 6 inner pixels adjacent to the boundary, respectively. If the above criterion is not met, no filtering is performed; otherwise, a 1-D low-pass filter is applied across the boundary as shown in Figure 3; the filter size is adaptive to the local gradients across the boundary so that filter with smaller size is applied to where lower gradient presents.

2.3 Pixel/Block classification and de-ringing

The pixel classification is performed by applying thresholds to the local variance values in terms of the following criteria:

$$pixel(x,y) \begin{cases} class\_0 & if\ \sigma^2(x,y) < thresh\_1 \\ class\_1 & if\ \sigma^2(x,y) > thresh\_2 \\ class\_2 & if\ thresh\_1 \leq \sigma^2(x,y) \leq thresh\_2 \end{cases}$$

Here, $\sigma^2(x,y)$ is the local variance value at pixel position (x, y), *class*_0 (low variance) represents pixels of smooth regions, *class*_1 (high variance) represents pixels on edges, and *class*_2 (medium variance) indicates pixels of texture regions. *Thresh*_1 and *Thresh*_2 are empirically set to 10 and 400, respectively. They are found to have very robust performance in various video sequences. Based on the pixel classification, each 8×8 block can be classified as smooth, edge or texture block. In our scheme, a block is decided to be an edge block if at least one edge pixel present in the block.

Since ringing artifacts usually occur around the sharp edges, the de-ringing operation skips all smooth and texture blocks and is applied to edge blocks only. In this operation, each pixel in the edge block is filtered by an edge preserving filter, i.e., the fuzzy identity filter, in a 5×5 window. In the following, we introduce the fuzzy identity filter in more details.

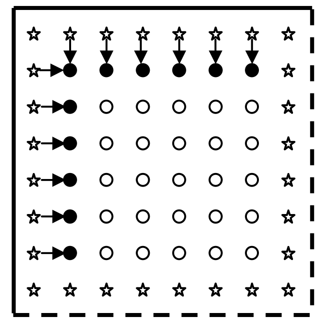

Figure 2. Blocking artifact detection based on variance differences within an 8×8 block.

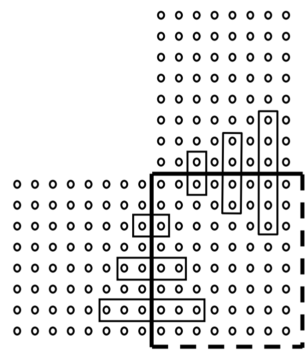

Figure 3. Blocking artifact removal using 1-D low-pass filter. Three possible filter sizes are shown at three sample positions.

2.4 Fuzzy identity filter

The fuzzy identity filter, which is derived from the fuzzy transformation theory [6], has been successfully applied to coding artifacts reduction recently [11]. This filtering technique directed by the classified edge map provides an optimal solution for ringing artifacts reduction. To see this, we briefly review the principle of fuzzy transformation and the edge preserving properties of the fuzzy identity filter.

In fuzzy transformation, relationships between each spatial sample x_i (i is the spatial index) and each order statistic $x_{(j)}$ (j is the rank index and $x_{(1)} \leq x_{(2)} \leq \ldots \leq x_{(N)}$) within an observation window are established through a real-valued fuzzy spatial-rank (SR) matrix, which is defined by

$$\tilde{R} = \begin{bmatrix} \tilde{R}_{1,(1)} & \cdots & \tilde{R}_{1,(N)} \\ \vdots & \ddots & \vdots \\ \tilde{R}_{N,(1)} & \cdots & \tilde{R}_{N,(N)} \end{bmatrix},$$

where $\tilde{R}_{i,(j)} = \mu_{\tilde{R}}(x_i, x_{(j)}) \in [0,1]$, $i, j = 1,2,\ldots N$, $\mu_{\tilde{R}}(a,b)$ is a membership function to compute the fuzzy relation between a and b with the following restrictions:

1. $\lim_{|a-b|\to 0} \mu_{\tilde{R}}(a,b) = 1$
2. $\lim_{|a-b|\to \infty} \mu_{\tilde{R}}(a,b) = 0$
3. $|a_1 - b_1| \le |a_2 - b_2| \Rightarrow \mu_{\tilde{R}}(a_1,b_1) \ge \mu_{\tilde{R}}(a_2,b_2)$

The Gaussian membership function $\mu_G(a,b) = e^{-(a-b)/2\xi^2}$ is used in this paper, where the spread parameter $\xi = 20$. Since the element values are dependent to the distance between each pair of samples, the fuzzy SR matrix contains the spread information embedded in the observation samples. The original (crisp) spatial samples can be "transformed" into fuzzy spatial samples by multiplying the crisp order statistics vector with the row normalized fuzzy SR matrix. The output of the fuzzy identity filter is just the fuzzy counterpart of the center sample in the observation (filtering) window, which can be obtained using the following simplified formula:

$$y = \tilde{x}_c = \frac{\sum_{j=1}^{N} x_{(j)} \mu_{\tilde{R}}(x_c, x_{(j)})}{\sum_{j=1}^{N} \mu_{\tilde{R}}(x_c, x_{(j)})},$$

where x_c and $\tilde{x}_c$ are crisp and fuzzy center sample, respectively. It is known that fuzzy transformation has the property that it clusters the similarly valued samples around their local mean and leave isolated samples unchanged. Therefore, fuzzy identity filter possesses a data-adaptive smoothing feature and thus can perfectly preserve the strong edges while removing weak ones. By applying fuzzy identity filter to the edge blocks only, we are able to removes annoying ringing artifacts, preserve edges and avoid unnecessary smoothing as well.

3. EXPERIMENTAL RESULTS

Six video sequences were used for the evaluations. These sequences were encoded and decoded using MPEG-2 TM5 codec with different quantization scale parameters. In order to compare the performance of the proposed algorithm with the existing methods, four typical methods are selected as references: the MPEG-4 filter described in [4], the wavelet-based filter in [7], the DCT-domain filter in [8] and the POCS approach described in [10].

One of the test sequence images is given in Figure 4 for the subjective comparison. It can be seen from the figures that the wavelet method is able to remove most blocking and ringing artifacts, but it also blurs the entire image. The MPEG-4 filter is good at de-blocking, but is unable to remove ringing artifacts. The POCS based method suppresses more ringing artifacts than MPEG-4, but also blurs the image like the wavelet method. The DCT filter maintains the sharpness of the image, however, like the MPEG-4 filter, it cannot remove the ringing artifacts successfully. It is evident from the subjective results that the proposed edge map guided edge preserving filtering method is the only method that is able to retain edge sharpness, yet still removes the ringing artifacts.

In terms of complexity, our proposed technique has very low complexity and is close to that of the MPEG-4 technique. The complexity of both techniques is much less than the other three techniques that have been evaluated.

4. CONCLUSIONS

In this paper, we proposed a new adaptive post-filtering scheme, which significantly reduces the blocking and ringing artifacts while preserving the image details. Based on the edge map information, an adaptive 1-D filter and a 2-D fuzzy identity filter are applied to remove blocking and ringing artifacts, respectively. The experimental results demonstrate the superior performance of the proposed algorithm compared with the existing methods that have been evaluated.

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(a) Decoded image; PSNR = 30.69 dB

(b) Wavelet result; PSNR = 29.86 dB

(c) MPEG-4 result; PSNR = 30.88 dB

(d) POCS result; PSNR = 30.12 dB

(e) DCT result; PSNR = 30.21 dB

(e) Proposed method result; PSNR = 30.93 dB

Figure 4. Objective and subjective results for the “News” sequence.