MERL – A MITSUBISHI ELECTRIC RESEARCH LABORATORY
http://www.merl.com

Edge Map Guided Adaptive Post-Filter for Blocking and Ringing Artifacts Removal

Hao-Song Kong, Anthony Vetro, and Huifang Sun

TR-2004-003   February 2004

Abstract

This paper presents a new adaptive post-filtering algorithm for blocking and ringing artifact reduction. The proposed method extracts local statistics and constructs an edge map of the image. Based on the edge map information, blocking and ringing artifacts are detected, and then reduced by an edge map guided filter. The proposed method specifically targets the blocking artifacts at the block boundaries and ringing artifacts close to edges. Therefore, the algorithm is able to preserve sharp edges and details, while reducing the artifacts. Experimental results demonstrate that our proposed post-filtering algorithm achieves better subjective and objective results compared with other methods. Also, the algorithm has very low complexity.

Publication History:

1. First printing, TR-2004-003, February 2004

EDGE MAP GUIDED ADAPTIVE POST-FILTER FOR BLOCKING AND RINGING ARTIFACTS REMOVAL

Hao-Song Kong, Anthony Vetro, and Huifang Sun

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

ABSTRACT

This paper presents a new adaptive post-filtering algorithm for blocking and ringing artifact reduction. The proposed method extracts local statistics and constructs an edge map of the image. Based on the edge map information, blocking and ringing artifacts are detected, and then reduced by an edge map guided filter. The proposed method specifically targets the blocking artifacts at the block boundaries and ringing artifacts close to edges. Therefore, the algorithm is able to preserve sharp edges and details, while reducing the artifacts. Experimental results demonstrate that our proposed post-filtering algorithm achieves better subjective and objective results compared with other methods. Also, the algorithm has very low complexity.

1. INTRODUCTION

Compression is used in a wide variety of applications, including digital cameras, broadcast and DVD. To increase the number of images stored to a disk or to reduce the transmission bandwidth of video, high compression techniques are often used in which the compression ratio is quite high. In this case, we may expect to see some visual artifacts due to the quantization and coefficient truncation process. Post-filtering is considered a practical solution to suppress the visual artifacts and guarantee the subjective quality of the image at the final step before rendering.

Most video coding standards such as ITU-T H.26x and MPEG-1/2/4 use block-based processing. At high compression ratios, a number of visual artifacts due to the underlying block-based approach can be observed. The artifacts studied most intensively are the blocking and ringing artifacts. The blocking artifacts appear as grid noise along the block boundaries in monotone areas. The ringing artifacts are more pronounced along sharp edges in low energy areas of the image. This is an effect of Gibb's phenomenon, which is caused by the truncation of the high-frequency coefficients, i.e., the quantization of the AC coefficients.

Many algorithms have been proposed for reducing the visual artifacts in compressed images/videos. Among these methods are adaptive spatial filtering methods, e.g., [1],[2], wavelet-based filtering methods, e.g., [3],[4], DCT-domain methods, e.g., [5], statistical methods based on MRF models, e.g., [6], and iterative methods, e.g., [7]. It should be noted that this is not an exhaustive list of post-filtering artifact reduction techniques, but we believe that most major categories are covered. Without going into details on each method, we have found that all of the proposed algorithms either blur the image too much in an effort to eliminate artifacts or cannot eliminate the artifacts sufficiently. Also, many of the existing approaches are too complex for practical use. Several of the above methods are simulated and compared to our proposed technique in Section 3. We reserve further discussion on the above existing techniques until then.

In this paper, we propose a new adaptive post-filtering algorithm, which significantly reduces the blocking and ringing artifacts. The proposed algorithm is based on edge map information and the local statistics around edges. Compared to existing methods that we have simulated, the proposed post-filter is able to preserve edges better and remove blocking and ringing artifacts effectively. The complexity of the proposed algorithm is very low, i.e., on the same order as the MPEG-4 filtering technique.

2. THE PROPOSED ALGORITHM

The basic idea of our proposed algorithm, which differs from the previous methods, is that we apply pattern classification techniques for filtering of artifacts. From the perspective of the human visual system, we know that each pixel serves a different role in the image. Since our visual system is very sensitive to high frequency changes, and especially to the edges in the image, edges are very important to our perception of the image. Therefore, our strategy is to classify the pixels in the image before performing the filtering [8]. If we know the edge position, then we can avoid filtering the edge pixels, yet still apply a filtering operation to the surrounding pixels. The proposed algorithm is schematically shown in Figure 1.

2.1 Extraction of local statistics and pixel classification

Since the local variance can accurately reflect the gradient of the image at each pixel location, we calculate the local statistics (mean and variance) for each pixel. To characterize the local statistics, a 3x3 window slides over each pixel in the image. The variance at each position forms the variance map of the image. The variance map is used as the edge map.

The variance in homogeneous regions is very small. To capture these areas, the pixels with low variance are classified together as class_0. On the other hand, areas with very high variance typically correspond to edges within the image. These pixels are classified as class_1. The variance between these two extremes can be considered as either ringing noise or texture depending on the characteristics of neighboring pixels. Pixels that fall into this in-between region are classified as class_2. The classification is obtained by applying thresholds to the variance values, which is summarized below:

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

Thresh_1 and Thresh_2 are determined experimentally and are set to 10 and 400, respectively. These two thresholds are robust values and are independent of the video sequence.

2.2 Block boundary detection and de-blocking

The block boundary detection is performed on 8x8 blocks in the edge map as shown in Figure 2. Blocking artifacts have very strong patterns on the block boundaries. The inner six variances (adjacently parallel to the block boundaries) in the edge map have almost the same gradients. Therefore, we use six variances on the top and left boundaries of each block to detect the blocking artifacts. The criterion for deciding that a blocking artifact is present is as follows:

$$\sum_{i=1}^{6} sign(*_i - 0_i) >= 5$$

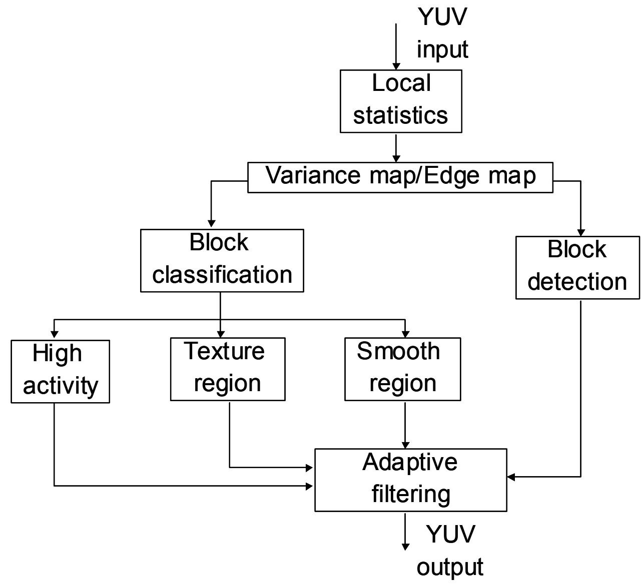

Figure 1. Proposed post-filtering algorithm.

A one-dimensional Gaussian filter is applied to the detected boundaries if the above criterion is met; otherwise, no filtering is required for these boundaries.

2.3 Block classification and de-ringing

According to the variance values in the edge map, block classification can be done easily. The blocks are marked as smooth block, high activity (edge) block, and texture block with small, high, and medium variance values, respectively. The de-ringing operation skips all smooth and texture blocks and goes to edge blocks directly. An adaptive 3x3 low pass filter is applied to the pixels surrounding the edges. Since the ringing noise and texture pixels have similar variance values, the filter with the large central weight is applied to the texture pixels far away from the edges to preserve the details, and the smooth filter is applied to the pixels near the edges to filter out the ringing noise.

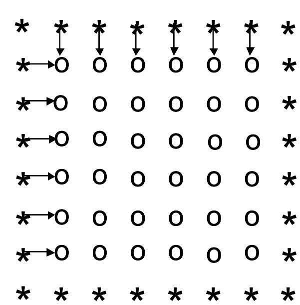

Figure 2. Block boundary detection based on pixel gradients within a block.

3. EXPERIMENTAL RESULTS

Two video sequences are used for the evaluation in this paper: Mobile and News. The sequences have a chroma format of 4:2:0 and frame frequency of 30Hz. The Mobile sequence has resolution 720x576 (interlaced), while the News sequence has 352x288 (progressive). Both sequences were encoded using MPEG-2 TM5 encoder. The total number of frames in each sequence is 100. The coding parameters are as follows:

- N=15, M=3
- Rate control: Off
- Search range = 32x32 for P and B frames
- Fixed Q-scale (26, 46, 62) for all frame types

In order to evaluate the performance of the proposed algorithm, four existing methods are selected as references: the MPEG-4 filter described in [2], the wavelet-based filter in [4], the DCT-domain filter in [5] and the POCS approach described in [7]. These reference methods were implemented and simulated for comparison to our proposed method.

Table 1 gives the PSNR results comparing the objective quality. Although PSNR is not a good measure to evaluate such techniques, improvements of the proposed approach over the wavelet, POCS and DCT-based methods is shown. Objectively, our results are closest to the MPEG-4 method, but as discussed below, the subjective results are quite different.

Table 1. PSNR Comparison in dB

	Decoded Video	Wavelet [4]	MP4 [2]	POCS [7]	DCT [5]	Edge Map
Mq62	26.23	24.42	26.20	24.72	25.13	26.24
Mq46	27.61	25.09	27.56	25.57	26.16	27.62
Mq26	30.66	26.17	30.51	27.15	28.13	30.50
Nq62	30.69	29.96	31.00	29.83	30.21	31.12
Nq46	32.11	30.84	32.40	30.99	31.39	32.61
Nq26	35.18	32.41	35.25	32.64	33.53	35.32

The subjective results for a portion of the Mobile sequence are shown in Figure 3. While the wavelet method is able to remove most blocking and ringing artifacts, it is quite blurred. The MPEG-4 filter does a good job in deblocking, but is not able to successfully remove ringing artifacts. The POCS based method removes more ringing artifacts than MPEG-4, but is also blurred as with the wavelet method. The DCT filter maintains the sharpness of the image, but as with the MPEG-4 filter cannot remove the ringing artifacts. It is evident from the subjective results that the proposed edge map guided method is the only method that is able to retain the edge sharpness, yet still remove 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 of these techniques is much less than the other three techniques that have been evaluated.

4. CONCLUSIONS

In this paper, an edge map guided adaptive post filter has been presented. In order to avoid unnecessary filtering, the proposed algorithm first performs pixel classification in terms of the local statistics in the image, then based on the blocking and ringing noise detection, applies adaptive filters to the detected pixels accordingly. The structure diagram in Figure 1 realizes a low complexity solution and the experimental results demonstrate a dramatic improvement in performance with the proposed algorithm compared to the existing methods that have been evaluated.

REFERENCES

[1] T. Jarske, Pl Haavisto, and I. Defe'e, "Post-filtering methods for reducing blocking effects from coded images," *IEEE Trans. Consumer Electronics*, Vol. 40, No. 3, pp. 521-526, Aug. 1994.

[2] ISO/IEC 14496-2:2001, "Information Technology – Generic Coding of Audio-Visual Objects – Part 2: Visual," *2nd Ed., Appendix F3 – Post – processing for coding noise reduction*, 2001.

[3] S. Mallat, and S. Zhong, "Characterization of signals from multiscale edges," *IEEE Trans. Pattern Anal. Machine Intell.*, Vol. 14, No. 3, pp. 710-732, July 1992.

[4] Z. Xiong, M. T. Orchard, and Y. Q. Zhang, "A deblocking algorithm for JPEG compressed images using overcomplete wavelet representations," *IEEE Trans. Circuits Syst. Video Technol.*, Vol. 7, No. 2, pp. 433-437, Aug. 1997.

[5] T. Chen, H. R. Wu and B. Qiu, "Adaptive post-filtering of transform coefficients for the reduction of blocking artifacts," *IEEE Trans. Circuits Syst. Video Technol.*, Vol. 11, No. 5, pp. 594-602, May 2001.

[6] T. Meier, K. N. Ngan and G. Crebbin, "Reduction of blocking artifacts in image and video coding," *IEEE Trans. Circuits Syst. Video Technol.*, Vol. 5, No. 3, pp. 490-500, Apr. 1999.

[7] A. Zakhor, "Iterative procedures for reduction of blocking effects in transform image coding," *IEEE Trans. Circuits Syst. Video Technol.*, Vol. 2, No. 1, pp. 91-95, Mar. 1992.

[8] H. Kong, and L. Guan, "A noise-exclusive adaptive filtering framework for removing impulsive noise in digital images," *IEEE Trans. Circuits and System*, Vol. 45, No. 3, pp. 422-428, Mar. 1998.

Figure 3. Subjective results from a portion of the Mobile sequence: (upper-left) decoded image, (upper-right) wavelet result, (middle-left) MPEG-4 result, (middle-right) POCS result, (lower-left) DCT result; (lower-right) proposed edge map result.