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A New Adaptive Post-Processing Method for Artifact Reduction in Video Coding Using Interpolation

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Abstract: Block-based low bit rate video coding is the most widely used method for storage and communication. This method even though increases compression they yield visually annoying artifacts that has to be reduced while decoding the compressed video data. Several methods are proposed for this in the literature, but most of them are for still images and has high computational complexity. In this study, we propose a new blocking artifact reduction algorithm using interpolation. Where instead of block, the block boundaries are classified using a simple statistical property of the pixels along the boundary and adaptively interpolated to reduce the artifacts using a low computational procedure. The computer simulation results confirm the low computational complexity and better performance of the proposed method.

Key words: Artifact reduction, low bit rate video coding, video decoder, interpolation

INTRODUCTION

Video coding technique based on the block coding is the most popular compression technique and has found many applications. Especially, block coding is used in both still image and moving image coding standards, such as Jpeg[1] and Mpeg[2]. Other block coding that involves partitioning is such as vector quantization[3], block truncation coding[4] and fractal-based compression[5].

But the main drawback of the block coding is the blocking artifacts[6]. This is due to the encoding of blocks without considering the correlation between adjacent blocks. In transform coding the high quantization of transform coefficients leads to blocking effect[6], but it becomes a major problem in block truncation coding and vector quantization. To reduce blocking artifacts while decoding, many post-processing algorithms have been proposed[8,9]. The post processing algorithms aiming at the reduction of compression artifacts improves the overall perceptual quality for a given bit rate or equivalently, increases the compression ratio with respect to a given quality requirement.

The post-processing algorithms are derived from two different viewpoints, i.e.,

- Image enhancements
- Image restoration. Filtering of frames around the block boundaries does first method and the later is done by constrained optimization and projection onto convex sets (POCS)[10]. Since the restoration algorithms usually take much computation time, the filtering technique is preferred for real-time implementation[11,12].

Designing an image enhancement algorithm typically relies on a two-step procedure. First, objectionable distortions are identified and modeled within the decompressed video sequence. Then, an operator is constructed to attenuate the distortion. For low-bit applications, enhancement techniques primarily remove blocking artifacts. For example, filtering the decoded image with a low-pass filter attenuates blocking[13]. But, excessive smoothing also removes important high-frequency content. Several techniques adjust the amount of smoothing to address this problem. Filtering may be restricted to the block boundaries and reduced when significant intensity differences are detected between neighboring blocks[11] and this preserves significant region boundaries. Alternatively, the visibility of each block boundary may be estimated through the use of a human visual system model and boundary is then smoothed until it is no longer visible[14]. Adaptive filtering[15] for video signals is applied to both spatial and temporal components iteratively to reduce blocking artifacts. This method reduces the computational complexity of ordinary-filters for images and increases the adaptation to local statistics of images.

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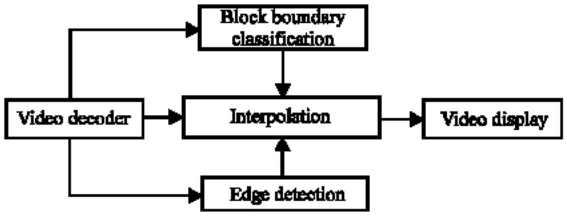


Fig. 1: The flow diagram of complete post-processing

However this method reduces the blocking artifacts considerably, when they are applied for video coding at the decoder but they are not viable because of the high computational complexity[16] relative to video decoder. Since already the decoding of video compressed data remains a huge task and if additionally these algorithms are applied the efficiency of the video decoder reduces considerably. The computational complexity of these algorithms is mainly due to:

- Pixel or block classification-as artifact are mainly due to boundary pixels between two successive blocks, rather this process is applied to all the pixels in the block.
- The adaptivity of filters is not robust.

In this study we propose a new post-processing algorithm, which exploits the statistical properties of pixels in the boundary of the blocks and classifies block boundary into flat, texture and edge regions using pixel difference in the block boundary. Based on this classification, we adaptively interpolate the pixels. The proposed method is developed considering the subjective quality of images, Signal-to-Noise Ratio (SNR) and computational complexity. Since we implemented a simple procedure for block classification and adaptive filtering of pixels, the computational complexity is considerably reduced along with error.

Proposed post-processing method: Interpolation is a very simple way to correlate the values with respect to its neighboring pixels. Using this we can create a linear polynomial, which is smooth and continuous along the block boundary reducing the blocking artifact. Since the pixels in the decoded images are not linear and correlated it is possible to over smooth the high frequency components and the edges. Hence we have to classify the block boundary so that we adaptively adjust the level of interpolation without changing the characteristics of the images. As shown in the Fig. 1, the reconstructed frames from video decoder are send to a simple block boundary classification method and edge detection method before get interpolated. The interpolation is done based on the output of both block boundary classification and edge detection method.

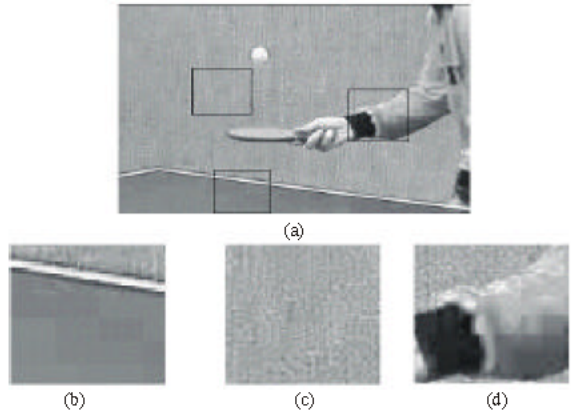


Fig. 2: Illustration of block boundary classification: (a) reconstructed image from MPEG 2 video file and the blocked regions with different characteristics (b) flat (c) texture and (d) edge regions

Block boundary classification: The classification of blocks remains a major issue in all the adaptive post-processing methods because:

- They increases the adaptivity of the method
- Preserves the high

frequency coefficients and edges. The block classifications are done either in pixel-domain or in DCT-domain. The DCT-domain approach remains the most efficient if the artifacts created are mainly due to DCT-based block coding[17]. However this method is unable to detect the blocking artifacts created by block based motion-estimation and vector quantization. Hence the pixel domain approach remains the most widely used method for block classification.

In most pixel-domain block classification algorithms[18,19] the blocks are classified based on analyzing all the pixels in the block and does not compare with pixels in the ambient blocks with which it actually creates the blocking artifact effect. Thus the computational complexity of this type of block classification is more.

In our method we are implementing a simple block boundary classification method, i.e., we are classifying only the block boundary not the blocks in the video frames, since the blocking artifact results mainly due to signal discontinuities across the block boundary. We are motivated by the observation that,

- Artifact is more annoying when there is same level of transition or discontinuity in the values of all pixels along the block boundary. (Fig. 2b)
- Artifact is not notable if the signal discontinuity is not consistent along the boundary. (Fig. 2c)

The above points can be easily visualized from the images shown in the Fig. 2 the Table tennis video frames of MPEG 2. The three regions of the reconstructed image are boxed and shown in Fig. 2b, 2c and 2d for reference. In the Fig. 2b we can see that blocks are more annoying as the difference in the pixels values is very consistent along the boundary between two flat pixel blocks. In the same figure the flat block that forms with an edge and texture block doesn't exhibit a noticeable artifact as due to non-consistency in signal distortion. In Fig. 2c, as there are artifact, as the blocks are texture region and since we did not have a consistent signal distortion, the artifact are not notably annoying. In Fig. 2d the block boundaries that lies along the edges does not produce much artifact effect. Thus artifact effect emitted by a block boundary between two blocks depends upon the surrounding pixels.

Hence we classify the block boundary by considering the pixels present around each boundary between the blocks. The difference D between the pixels lying on either side of the boundary in calculated as

$$D_x = \text{abs}\,(p_{i,j} - p_{i,j+1}),\ 0 \leq x \geq n,$$

Where, n is the size of the block and $p_{i,j}$ is the pixel at position (i, j). The values of i remains multiple of n for horizontal boundaries of blocks and the values of j remains multiple of n for vertical boundaries of blocks. The mean E and the variance V are calculated from the values of D, which are used to classify the block boundary.

If variance V < th_flat and mean E lies between certain values i.e., m<E<n then block boundary is classified as flat boundary.

Else If variance V < th_texture and E is less than certain threshold value E<p to classify block boundary as texture boundary and if V> th_edge then the block boundary are classified as Edge boundary. The threshold values th_flat, th_texture, th_edge and the limits m, n and p determine the sensitivity of the images.

Reduction of blocking artifact by interpolation: Since interpolation is used for the construction of polynomials, we are using the Lagrange interpolation for the reconstruction of block boundaries in the video coded frame. The video frame, which are considered as a two-dimensional matrix is here consider as a separate one-dimensional array of polynomials in each row and column format. Interpolation is performed to this low frequency block. In a large flat area, the difference of coefficients from adjacent blocks can cause severe blocking effects, which are not limited on block boundary area. Hence there is a break in the normal flow of pixel. In our method we are considering the values of pixel in row

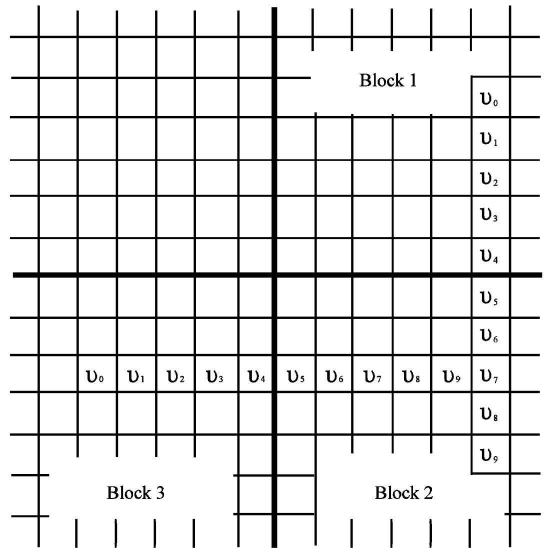


Fig. 3: Position of interpolated pixels in vertical and horizontal directions

wise and column wise as continuous polynomial function. Here we are considering artifact as a discontinuity in the normal flow of the polynomial. Hence using interpolations, we predict pixel values at the block boundaries. These predicted values are used for the reconstruction of polynomials and thus reducing artifacts.

In this method interpolation is applied to the pixels in the boundary in a step-by-step method. Since during interpolation we are taking more than two pixels for consideration the values of the pixel determined is more accurate. For a set of data points n and n > 1 the elementary Lagrange interpolation formula is given by,

$$l_i^n(x) = \prod_{j=1, j\neq i}^{n} \frac{x - x_j}{x_i - x_j}, \quad i = 1, 2, 3, ..., n \qquad (1)$$

$l_i^n(x)$ is a polynomial with degree no greater than n-1. Its value at any data point x_k within the data set is either 1 or 0, which is equivalent to

$$l_i^{\,n}(x_k) = \delta_{ik} = \begin{Bmatrix} 1, & i = k \\ 0, & i \neq k \end{Bmatrix} \qquad (2)$$

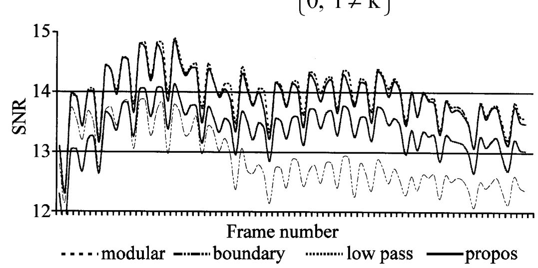
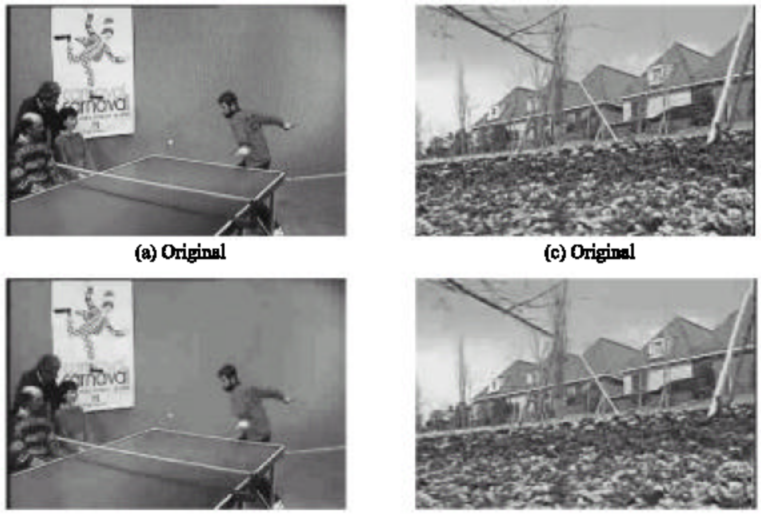


Fig. 4: SNR comparisons of various post-processing algorithm for the table tennis video sequence


(a) Original (c) Original

(b) Compressed (d) Compressed

Fig. 5: Original and compressed images of table tennis and flower garden video sequence

Here we are following a three-step procedure, so that we have better reconstruction of signals in the block boundaries. Thus we interpolate the pixels from v_0 to v_9 along the block boundary based upon the block boundary classification and edge detection.

The algorithm for interpolation is given by,

Step 1: for all block boundaries both horizontal and vertical do the following steps 2 to step 4.

Step 2: if the block boundary is classified as flat block then, the interpolating formula (3) is applied to pixels v2 to v7

$$v_n = (-1\times v_{n-2} + 4\times v_{n-1} + 4\times v_{n+1} - v_{n+2})/6 \quad (3)$$

Step 3: Else if it is a texture block the equation- 4 is applied for pixels v4 and v5

$$v_n = \frac{((v_{n-1}+v_{n+1})/2) + v_n}{2} \quad (4)$$

Step 4: stop the execution.

Experiments and result: Experiments were carried out to evaluate the performance of various post-processing algorithms. The algorithm is checked with various standard sample sequences and the error is calculated. The samples are decoded with MPEG 2 standard with a uniform quantization factor. The proposed algorithm is also checked with other algorithms like:

- Modular Post-Processing Scheme (MPS)[20])
- Reducing Quantization Effect (RQE) method BPM)[21]
- Low Pass Filter method[22] for comparative study.

Table 1: SNR comparisons of video files processed by various post-processing algorithms

			SNR values			
Video	Size	bpp	MPP	RQE	LPF	Prop
Table tennis	352×240	0.0335	13.31	12.36	12.67	13.26
Flower garden	352×240	0.0387	12.59	11.36	12.08	12.58
Bicycle	352×240	0.0328	11.66	10.08	11.01	11.57
mobile	352×288	0.0319	12.86	10.84	12.60	12.81
Susie	352×240	0.0289	13.58	13.10	12.50	13.46

Table 2: Computational time comparison of various post-processing algorithms

	Time (in seconds)			
Video	MPP	RQE	LPF	Prop
Table tennis	6.44	3.35	2.81	2.97
Flower garden	4.23	3.38	2.71	2.85
Bicycle	4.02	3.64	2.71	2.99
mobile	4.84	4.35	3.27	3.58
Susie	7.07	3.32	2.81	2.99

Table 1 shows the SNR values averaged over for hundred frames for various video sequences for different post-processing algorithms and compared with the original video sequence. The SNR performance of various post-processing algorithm is given in graphical format for first hundred video frames of Table tennis is given in Fig. 4. Table-2 shows the computing performance of the post-processing algorithm calculated on AMD-Athlon XP -1700 MHz machine with 128 MB ram and running REDHAT ™ Linux 8.0 system. The Table gives the time for which each process used the CPU in seconds.

We see form the Table 1 and graph in Fig. 4, that the MPP has the best SNR performance, but the processing time is much longer than other methods due to high computational complexity. The LPF, which has the best computational time but the SNR performance is low. The proposed method provides SNR performance is comparable with MPP and at the same time has low computational complexity equivalent to LPF. Though the SNR performance gives the level of error present in the images, but when considered to human perception they are not the best evaluator of post-processing algorithm. Hence to analysis the subjective quality of sample images of the original, compressed and reconstructed compressed images are shown in Fig. 5a-5d. It was found the MPP and proposed method achieves better subjective quality. The LPF and RQE method does not remove much artifact from the images.

CONCLUSION

In this study, we propose a new post-processing method to reduce the blocking artifacts by processing the spatial components so that it readily applied to real time video decoder. The proposed algorithm classifies the block boundary by analyzing the statistical property of the pixels and reduces the artifact adaptively by correlating the pixels by interpolation based on the block boundary classification.

The experimental results obviously show improvement of subjective quality while maintaining image details with low computational complexity. Hence the proposed method can effectively used for artifact reduction in block coded and low bit compressed video coding.

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