Postprocessing Algorithm for Quantization Noise Reduction Using Block Classification and Adaptive Filtering

Seung-Jin Lee, Suk-Hwan Lee, Seong-Geun Kwon, Jong-Won Lee, and Kuhn-Il Lee
School of Electronic and Electrical Engineering, Kyungpook National University
1370 Sankyukdong Pukku, Taegu 702-701, Republic of Korea

Abstract

In this paper, we proposed a postprocessing algorithm for the quantization noise reduction in the block coded images using the block classification and the adaptive filterings. The proposed algorithm consists of the block classification, the adaptive inter-block filtering, and the intra-block filtering. First, each block is classified into one of seven classes based on the characteristics of 8×8 DCT coefficients. And then, according to the information of various patterns and frequency distributions, in which are given by the block classification, the adaptive inter-block filtering is performed at the horizontal and vertical block boundary to reduce the blocking artifacts. Finally, within blocks which are classified into complex class, the intra-block filtering is performed to reduce the ringing noise without blurring edge. Experimental results show that the proposed algorithm gives better results than the conventional algorithms from both a subjective and an objective viewpoint.

1. Introduction

Recently, the block DCT-based coding is adopted in many international standards, such as JPEG, H.263, and MPEG. But, due to the quantization process which independently quantize the DCT coefficients in each block, compression artifacts are observed in the block-based coding. Among the artifacts caused by the quantization process, the blocking artifacts, in which include the grid noise and the staircase noise, and the ringing noise are most visible. The grid noise is easily noticeable to a slight change of intensity along 8×8 block boundary in the monotone area, as like a grid shape. When the continuous edge is included in the inter-block, this edge may be discontinuous. This discontinuous edge is called the staircase noise. Because of the truncation of the high-frequency coefficients in the quantization process, the pseudo-edge is noticeable around edge, as the Gibb's phenomenon; it's called the ringing noise.

Many postprocessing algorithms have been proposed to remove the quantization noise[1]~[7]. Among the algorithms, the filtering algorithms in the spatial domain[1]~[3] have the advantage of simple algorithm, ease hardware implementation, and good image quality. In Ramamurthi's algorithm,[1] each block is classified to the monotone area and the edge area, and a 2-D filter is performed to remove the grid noise in the monotone area, and a 1-D filer is performed to remove the staircase noise along the edge. However, the classifier can not discriminate between an L-shaped edge segment and a diagonal edge segment. H. Kim's algorithm[2] was proposed to remove the blocking artifacts using SAF on based of global, local, and contour edge map. This algorithm works well in the grid noise but not in the staircase noise at the inter-block.

Therefore, the postprocessing algorithm must be need to accurately classify each of blocks and preserve the image details. In this paper, the postprocessing algorithm is proposed to remove the quantization noise by using the block classification and the adaptive filtering. Each of blocks is classified into seven classes according to the distribution of the DCT coefficient. Considering of the filtering direction as well as the pattern of each class, the inter-block filtering is performed in the block boundary. The intra-block filtering is performed within blocks which are classified into the complex class. Computer simulations were made by using Baseline JPEG[8] and MPEG TM5.[9] It could be confirmed that the proposed algorithm was presented to reduce the artifacts and improve the discontinuity of edge at the block boundary.

2. The proposed method

The proposed algorithm finds the detailed information of the blocks, such as the block patterns and the frequency distributions, using the characteristic of DCT coefficient. According to the information of each block, the adaptive inter-block filter is performed to reduce the blocking artifacts at the horizontal and vertical block boundary, while preserving the pattern of blocks. And within only blocks with the high frequency, the inter-block filter is performed

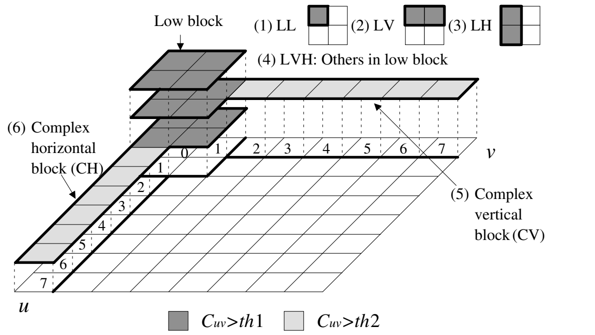


Figure 1: *Block classification using 8×8 DCT coefficient, C_{uv} distribution.*

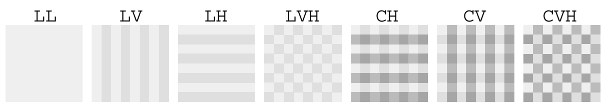


Figure 2: *The block patterns of 7 classes in the spatial domain.*

Table I*. Horizontal block filtering method.*

Current block \ Neighbooring block	LL LH	LV LVH	CH	CV CVH
LL, LH	1	2	3	4
LV, LVH	2	2	3	4
CH	3	3	3	4
CV, CVH	4	4	4	4

1: 1D 7-tab filtering, 2: 2D 3-tab filtering
3: 1D 3-tab filtering, 4: Pixel adjustment on the block boundary

Table II*. Vertical block filtering method.*

Current block \ Neighbooring block	LL LV	LH LVH	CV	CH CVH
LL, LV	1	2	3	4
LH, LVH	2	2	3	4
CV	3	3	3	4
CH, CVH	4	4	4	4

1: 1D 7-tab filtering, 2: 2D 3-tab filtering
3: 1D 3-tab filtering, 4: Pixel adjustment on the block boundary

to remove the ringing noise by using the edge detection and 3×3 SAF. [2]

2.1. The block classification

To find the various patterns and the frequency distributions of block, each block is classified into one of seven classes according to the distribution of 8×8 DCT coefficient, C_{uv}, in which u and v indicate respectively the horizontal and vertical frequency coordinate. The block classification process is as follows:

```
for(u=1;u <8;u++)
  for(v=1;v <8;v++){
    if(!(u==1&& v==1))
    if(C_uv >th2)   block=CVH;}
for(i=2;i <8;i++) {
    if(C_ui >th2) v_temp +=1;
    if(C_iv >th2)h_temp += 1; }
if(v_temp >0 && h_temp >0 )
      block = CVH;
else if(v_temp >0 && h_temp==0)
      block = CV;
else if(v_temp==0 && h_temp >0)
      block = CH;
if( C_01 <th1 && C_10 <th1 && C_11 <th1)
      block = LL;
else if(C_01 >th1 && C_10 <th1 && C_11 <th1)
      block =LV;
else if(C_01 <th1 && C_10 >th1 && C_11 <th1)
     block =LH;
else block = LVH;
```

As the inter-block filtering can be performed in the horizontal and vertical direction, blocks are classified into seven classes according to flat, complex, horizontal, and vertical pattern. Fig. 1 shows this classification process.

2.2. Adaptive inter-block filter

Considering both the frequency characteristic and the filtering direction, the adaptive inter-block filtering is performed at the horizontal and vertical inter-block boundary. In the horizontal filtering, if seven classes are reclassified in the similarity of the horizontal maximum bandwidth, they can be reclassified to four properties such as {LL,LH}, {LV,LVH}, {CH}, and {CV,CVH}. Likewise, in the vertical inter-block filtering, seven classes can be reclassified to four properties such as {LL,LV}, {LH,LVH}, {CV}, and {CH,CVH}.

2.2.1. The coefficients of the adaptive filter

The inter-block adaptive filter is designed by using the 1D spectrum of the reclassified classes in the horizontal inter-block filtering. With {LL,LH}, {LV,LVH}, and {CH}, in which have the finite horizontal maximum bandwidth, three adaptive filters are respectively designed into the spectrum of three cases. The filter tap number and the filtering region are determined in a viewpoint of the image quality and PSNR. Each of the 1D horizontal spectrum in three cases is given by

$$\begin{aligned} &\hat{H}_{LL}(v), \hat{H}_{LH}(v) = [h_{11}\ h_{12}\ h_{13}\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0] \\ &\hat{H}_{LV}(v), \hat{H}_{LVH}(v), \hat{H}_{CH}(v) = \\ &\qquad [h_{21}\ h_{22}\ h_{23}\ h_{24}\ \ 0\ \ 0\ \ 0\ \ 0] \end{aligned} \tag{1}$$

The filter coefficients $\hat{\boldsymbol{h}}$ can be approximated by Moore-Penrose generalized inverse matrix [8] which defined as

$$\hat{h} = (C^T C)^{-1} C^T H = C^T H \tag{2}$$

where matrix $\boldsymbol{C}$ is given by

$$C(u,x) = \alpha(u)\cos[(2x+1)u\pi/2N] \tag{3}$$
$$where\ \ \alpha(u) = \begin{cases} \sqrt{1/N}, & u = 0 \\ \sqrt{2/N}, & u \neq 0 \end{cases}$$
$$0 \le u < N \quad 0 \le x < n$$

$\boldsymbol{C^T}$ is transpose matrix of $\boldsymbol{C}$ and $\boldsymbol{H}$ is the 1D horizontal spectrum in (1). Based on the spectrum of {LL,LH}, 1D 7-tap filter coefficient is calculated by using N=8 and n=4 in (3), in which $\boldsymbol{H}$ is $\hat{H}_{LL}(v)$, $\hat{H}_{LH}(v)$ in (1). As a similar manner, based on the spectrum of {CH}, 1D 3tap filter coefficient is calculated by using N=8 and n=2 in (3), in which $\boldsymbol{H}$ is $\hat{H}_{CH}(v)$ in (1). In case of having the different pattern as compared with the filtering direction, there is both the horizontal and vertical spectrum in two neighboring blocks or one block with these patterns. Therefore, based on the horizontal and vertical spectrum of {LV,LVH}, separable 2D 3tap filter is employed with identical spectrum in the horizontal and vertical directions, which it is calculated by extending 1D 3tap filter to 2D.

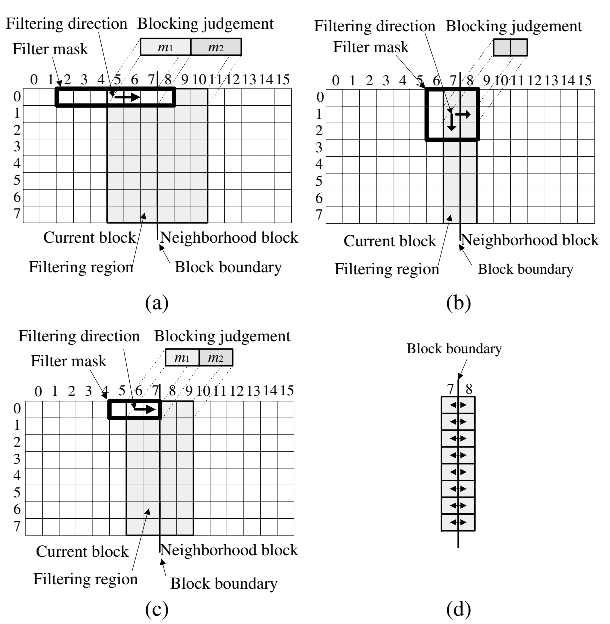


Figure 3: *Four block filtering method and the simple discrimination of blocking artifacts (a) 1D 7tab filtering, (b) 2D 3tab filtering, (c) 1D 3tab filtering, and (d) pixel adjustment on the block boundary.*

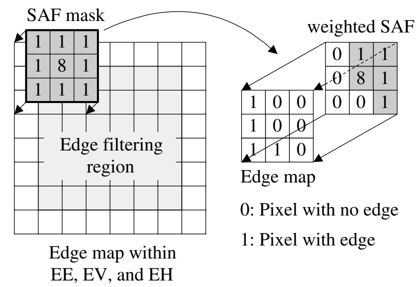


Figure 4: *The intra-block filtering method using SAF.*

2.2.2. The horizontal and vertical inter-block filtering

On the basis of the class with high spectrum in two neighboring classes, the blocking artifacts are removed by filter which is designed by it's spectrum, as shown in table I, table II, and fig. 3. To begin with, the inter-block filtering is performed only if two mean values of the pixel intensity within the inter-block's filtering region have the difference over 2, as shown in fig. 3. As shown in table I-(4), to remove the staircase noise in the inter-block, the intensities of two pixels is adjusted as follows;

$$m = |p_7 - p_8|/4 \tag{4}$$
$$\begin{cases} p_7 = p_7 - m, \ \ p_8 = p_8 + m, & if \ \ p_7 > p_8 \\ p_7 = p_7 + m, \ \ p_8 = p_8 - m, & if \ \ p_7 < p_8 \end{cases}$$

where p_7 and p_8 is respectively the pixel intensity of 7th and 8th location at the inter-block boundary.

2.2.3. The intra-blcok filtering

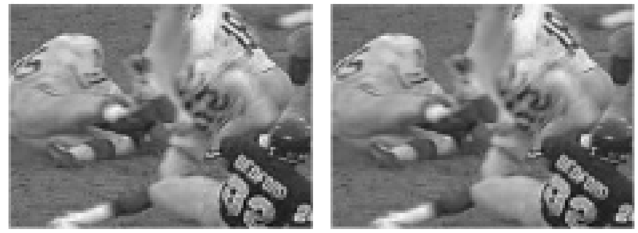
The high spectrum means that the block includes the edge of an image. In the proposed algorithm, the intra-block filtering is a convolution operation in which the weighting factors for the convolution are varied according to the edge map. Each pixel gradient is found by applying the sobel operator to blocks classified by {CH,CV,CVH}. The edge map is found as follows;

IF($Gradient[i][j] > th$) $\quad Edgemap[i][j]$=1
ELSE $\quad Edgemap[i][j]$=0

where th is experimentally determined to 8×qf and i,j is the location of the pixel in {CH,CV,CVH} classes. 3×3 SAF on the basis of the edge map is shown in fig. 4. SAF is performed only if the edge map in current pixel, in which is located on the center point of SAF mask, is 0. In that case, if the edge map in neighboring eight point of SAF mask is 1, a weighting factor at this point is assigned to 0.

(a) (b)

Figure 5: (a) JPEG decoded image (0.45 bit/pixel) and (b) postprocessed images by the proposed algorithm.



(a) (b)

Figure 6: (a) MPEG decoded 17th. frame (B picture) in 1.5 Mbps and (b) postprocessed frame by the proposed algorithm.

Table III. PSNR of postprocessing on JPEG decoded images.

Test image	qf	Compre-ssion ratio	PSNR [dB]			
			Decode image	Ramam-murthi	Kim	Proposed method
LENA	32	15:1	32.52	32.58	32.70	32.76
	48	18:1	31.31	31.50	31.68	31.77
	62	20:1	30.74	31.00	31.18	31.24
BOAT	32	15:1	33.26	33.22	33.39	33.57
	48	18:1	31.86	32.01	32.19	32.29
	62	21:1	30.88	31.13	31.29	31.37

Table IV. Average PSNR of postprocessing on MPEG decoded images.

Test sequences	PSNR [dB]		
	Decode sequences	Kim	Proposed method
FOOTBALL 1Mbps	32.58	32.70	32.76
FOOTBALL 1.5Mbps	31.50	31.68	31.77

3. Experimental results

To demonstrate the performance of the proposed algorithm, computer simulations were performed in the baseline-JPEG and MPEG TM5. In the proposed algorithm, threshold value, $th1$ and $th2$, in the block classification were respectively $0.25 \times qf$ and $0.5 \times qf$ using the quantization scale factor, qf. And $h_{11}, h_{12}, h_{13}, h_{21}, h_{22}, h_{23}, h_{24}$ in (4) were respectively 1, 0.5, 0.2, 1, 1, 0.5, and 0.2 on the basis of C_{uv} distribution in fig. 1.

In the experiment of still image, LENA and BOAT of 512×512 size in the Baseline JPEG coded at the various bit rate were used. Table III of the experimental results in JPEG shows that PSNR of the proposed algorithm is 0.05 $\sim$ 0.3 dB higher than that of the conventional algorithm. LENA coded JPEG in 0.45 bit/pixel is shown in fig. 5(a), in which is a magnified portion of the image to demonstrate clearly the grid noise in the monotone area, the staircase noise around edge, and the ringing noise around eye. The postprocessed image by the proposed algorithm is shown in fig. 5(b). Subjectively, It can be seem that most of the grid noise and the staircase noise has been removed by the inter-block filtering and the ringing noise has been removed by the inter-block filtering without blurring image details. In the experiment for the moving picture, FOOTBALL 30 frames coded on the base of MPEG TM5 were used. Its sequence was compressed at the condition that GOP is 12, I/P frame distance is 3, 25 frame/sec, and the progressive scan method at 1 Mbps and 1.5 Mbps. In this experiment, threshold values in the block classification were determined by using the quantization parameter per macro block. Table IV is shown that the average PSNR of the proposed algorithm is 0.05 dB higher than that of the conventional algorithm. Fig. 6 (a) and (b) shows respectively the 17th frame coded MPEG in 1.5 Mbps and the postprocessed frame by the proposed algorithm. As shown in fig. 6 (a), it can be seem that the blocking artifacts are not shown in the complex background because of the masking effect, but easily shown in the monotone region and fast motion region and the ringing noise are easily shown in the edge region. The postprocessed frame can be seem to remove the blocking artifacts and the ringing noise without blurring image details as well as improve the discontinuity of edge in the inter-block. Also, in the experiment of the different image, we could confirmed that the performance of the proposed algorithm was better than that of the conventional algorithm in a viewpoint of PSNR as well as a subjective image quality.

4. Conclusions

In this paper, a new postprocessing algorithm was proposed to reduce the blocking artifact and the ringing noise using the block classification and the adaptive filtering. Each of blocks is classified to 7 classes according to the distribution of 8×8 DCT coefficient. After the comparision of the neighboring two classes, the inter-block filtering was performed to remove the blocking artifacts at the horizontal and vertical block boundary by using three adaptive filters, in which was approximated to the finite horizontal spectrum of the reclassified classes. The inter-block filtering was performed to remove the ringing noise by using the edge detection and SAF within blocks classfied to the complex class. In the experiments of JPEG and MPEG at various images, the performance of the proposed algorithm could be confirmed that was better than that of the conventional algorithm in a viewpoint of PSNR and a subjective image quality.

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