ABSOLUTE ESTIMATION METHOD OF MOSQUITO NOISE FOR A POST FILTERLING

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ABSTRACT

In a DCT coding, degradations called block artifact and mosquito noise are appeared in reconstructed pictures. They should be reduced in post processing after decoding without superabundant processing. However, an estimation of mosquito noise is rare because of its difficulty. To realize an estimation of mosquito noise level, we extract a block that mosquito noise will be easy to occur. Mosquito noise level is calculated at a selected side of the block. In this processing, only the sides of high probability block are used. Then, a block value is taken by averaging. Finally, the picture value is calculated by averaging of this. Estimation method is evaluated by using the MPEG-4 decoded pictures. Quantization scale of coding and the estimated mosquito noise level are compared. As the results, we recognize the proposed method gives almost reasonable mosquito block and absolute level. Father, adaptive filter is controlled by the estimated mosquito noise level. It is recognized that the high quality of decoded picture is kept and the mosquito noise is reduced effectively at the picture with degradation.

Keywords: Mosquito noise, Objective picture quality, Post filtering

1. INTRODUCTION

In a picture coding, DCT (Discrete Cosine Transform) processing has an advantage in efficiency, and widely used in JPEG and MPEG or others. However, degradations called block artifact and mosquito noise are appeared in reconstructed pictures. Because they are un-natural degradation, they should be reduced in post processing after decoding.[1]

To avoid superabundant processing, an objective estimation of these artifacts to control the filtering is required. Many methods for block artifact were proposed, and almost linear evaluation to artifacts quantity was achieved. However, an estimation of mosquito noise is rare because of its difficulty.[2][3]

To realize an estimation of mosquito noise level, we have proposed a method.[4] This time, we review it, and change the algorithm. At first, we extract a block that mosquito noise will be easy to occur. Last time, we took simple decision as a mosquito block or not. This time, the estimation of probability of mosquito noise is shown as the six levels. This magnitude is also useful for the control of the filter.

A mosquito noise level is calculated at a selected side of the block. In this processing, only the sides of high probability block are used. Then, a block value is taken by averaging. Finally, the picture value is calculated by averaging of this.

They are evaluated by using the MPEG-4 decoded pictures. This time, we use the ten sequences with various types. Quantization scale of coding and the estimated mosquito noise level are compared.

2. POST FILTER AT DECODING

2.1 Artifact of Decoded Picture

In the coding using DCT, specific artifacts occur by quantization and de-quantization of coefficient of DCT.

Examples of these artifacts are shown in Fig.1. Block artifact are un-smoothness at a border of block. It is caused by a lack of correlation of quantization error between blocks. Estimation of degree is relative easy by comparison of inter- and intra-block differences.

Also mosquito noise is quantization error. In a DCT / ICDT processing, quantization error of coefficients are spread inside a block by inverse transformation. In the case of motion picture coding, shape of noise is changed, and, it looks like mosquito. It can be seen at an edge of object. However, it is difficult to see at a part of complicated texture.

Block Artifact — Mosquito Noise

Fig.1 Artifacts of Decoded Picture

2.2 Control of Post Filter

Artifact should be reduced by post-filtering of decoder. Fig. 2 shows a structure of an adaptive post-filter. Inter-block filter reduces block artifact, and adaptive filter is effective for mosquito noise.

However, post processing is an adaptive low pass filter, and, superabundant processing causes blur of picture quality. To avoid such blur, an objective estimation of these artifacts to control the filtering is required.

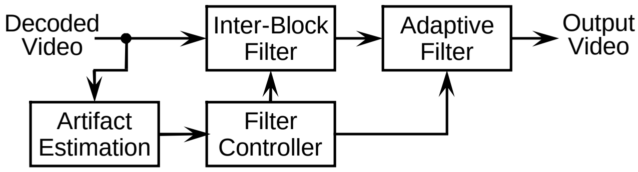


Fig.2 Structure of the Post Filter

2.3 Requirements for Noise Estimation

To estimate mosquito noise level, first important point is "Non reference picture". To use for post processing, reference picture can not be used. Also, inside of decoder, some information of decoding, such as quantization scale or macro block type of encoding, can be useful. However, in the pure post processing, such as in a display system, we can not use them.

Next important performance is "absolute quantity". It is required that estimated result of noise starts with fixed value. About a control of filtering, relative value is not useful, because, we should decide a filtering by an estimated noise level only. This is a very important performance to avoid filtering for non degraded pictures.

Sensitivity and linearity are required also. However, subjective picture quality depends on a picture very much.

About a unit of estimated value, both a block and a picture are required. A value at a block is useful to control filtering. However, it is not reliable generally. A value of a picture is useful as a reliable level.

2.4 Structure of Proposed Estimation

To realize an estimation method with the requirements, we take two steps of processing on the whole. First step is a probability estimation of mosquito noise occurrence for each block. Second step is an estimation of mosquito noise level.

Fig.3 shows the structure of the proposed estimation method. The probability of mosquito noise B_m at each block is estimated first. B_m is determined by using only texture pattern and block relation of a picture. Therefore, B_m is disturbed some by degradation of decoded picture.

The mosquito noise level at a block is calculated at the useful sides of a mosquito block that has high B_m. To estimate reliably, useful sides are limited strictly. For the both processing, flatness B_f of a block is also calculated.
Finally, mosquito noise level of a picture ML is estimated.

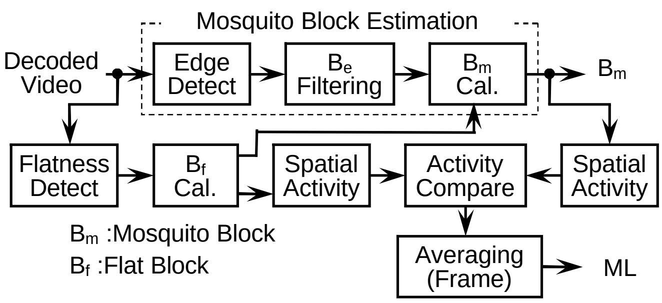


Fig.3 Structure of the Proposed Estimation

3. ESTIMATION OF MOSQUITO BLOCK

3.1 Edge Detection

The probability of mosquito noise B_m is derived from the shape of picture. At first, we extract edge by using Sobel filter. Fig.4 shows the filter coefficients and the calculation of edge detection.

To estimate a block performance, the sub-block value E_4 of edge is calculated by next.

$$E_4(bx,by) = \frac{1}{4\times 4}\sum_{j=0}^{3}\sum_{i=0}^{3}E(bx+i,by+j) \qquad (1)$$

where
bx, by: address (horizontal / vertical pixel number at left upper position)
i, j: intra block address (horizontal / vertical)
The size of sub-block is 4x4 pixel, and is divided from a block that have 8x8 pixel.

Vertical(V)

1	2	1
0	0	0
-1	-2	-1

Horizontal(H)

1	0	-1
2	0	-2
1	0	-1

$$E = \sqrt{V^2 + H^2}$$

Fig.4 Edge Detection by Sobel Filter

3.2 Operation of Edge Value

In the four sub-block values at a block, we take the difference between the maximum value E_{4max} and the minimum value E_{4min} as the block value E_8 by next.

$$E_8(bx,by) = E_{4\max}(bx,by) - E_{4\min}(bx,by) \qquad (2)$$

Fig.5 shows example of the relation between sub-block value and block value. At least, if a sub-block in a block has high value, block value is high. However, if all values of sub-blocks in a block are high, block value becomes low. In such case, a lot of texture masks a mosquito noise. E_8 is not a final probability. But, used for the final estimation of mosquito block.

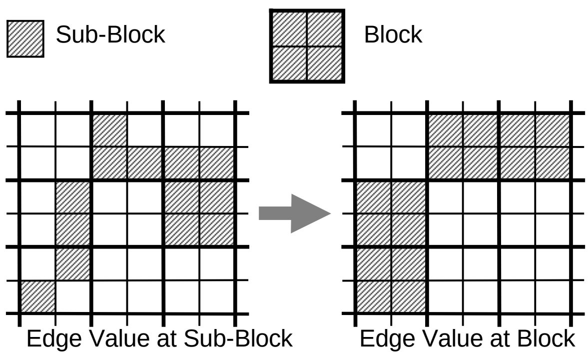


Fig.5 Block and Sub-Blocks

3.3 Flatness Detection

On the other hand, we calculate a variance of each block as flatness of a block. To decide flat block B_f, average *Ave* of a block is calculated from pixel value P by equation (3). Variance σ^2 of each block is given by equation (4) with using Ave.

$$Ave(bx,by) = \frac{1}{8\times 8}\sum_{j=0}^{7}\sum_{i=0}^{7} P(bx+i, by+j) \tag{3}$$

$$\sigma^2(bx,by) = \frac{1}{8\times 8}\sum_{j=0}^{7}\sum_{i=0}^{7}\{P(bx+i,by+j) - Ave(bx,by)\}^2 \tag{4}$$

Finally, flat block B_f is decoded form σ^2 by next.

$$B_f(bx,by) = \begin{cases} 1 & if \ \ \sigma^2 \le Tha \\ 0 & if \ \ \sigma^2 > Tha \end{cases} \tag{5}$$

This time, we take 50 as the threshold value Tha.

3.4 Estimation of Mosquito Block

Finally, probabilities of mosquito block B_m are decided by using the difference and flatness of neighbor blocks. The combination of high difference and many flat neighbors give high B_m.

The decision criteria are shown in Table.1. In the table, N_f is the number of flat blocks surrounding a target block. B_m have 6 class, 0 means least, and 5 means highest probability. Fig.6 shows typical cases of mosquito block (B_m = 5) and non-mosquito block (B_m = 0).

Table 1. Decision of mosquito block B_m

E_8 \ N_f	0	1	2	3	5	6-8
=< 22	0	0	0	0	0	0
22 <	0	1	1	1	1	1
24 <	0	1	2	2	2	2
26 <	0	1	2	3	3	3
28 <	0	1	2	3	4	4
30 <	0	1	2	3	4	5

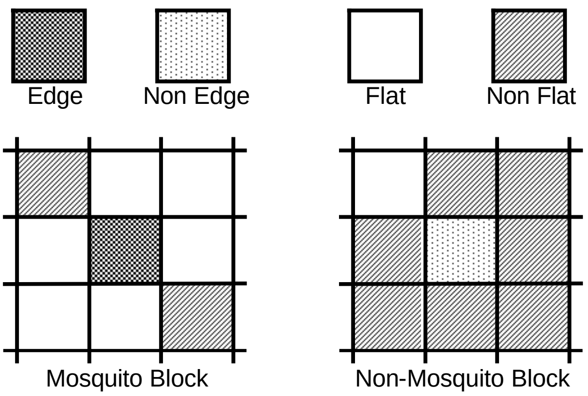


Fig.6 Estimation of Mosquito Block

4. ESTIMATION OF NOISE LEVEL

4.1 Useful Side in Mosquito Block

To estimate the level of mosquito noise, we decide which sides are useful to calculate it. Useful sides are located at the border of a mosquito block and a flat block as shown in Fig.7. This time, we use any class of mosquito block (B_m > 0). The other sides in a block are not used for estimation. Of course, the sides of non-mosquito block (B_m = 0) are out of estimation.

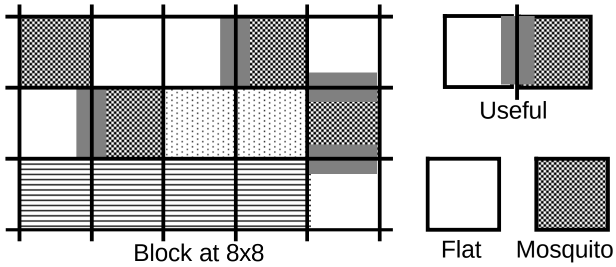


Fig.7 Useful Side at Block

4.2 Estimation of Noise Level at a Side

Pixel activities are calculated inside of mosquito block and outside of the border. Pixels to calculation are shown in Fig. 8. The calculation is a simple summation of spatial differences. In the case of vertical border, the inside activity A_m (right block) and the outside activity A_f (left block) are given by next.

$$A_m(bx,by,0) = \sum_{j=0}^{7}|P(bx,by+j) - P(bx+1,by+j)| \tag{6}$$

$$A_f(bx,by,0) = \sum_{j=0}^{7}|P(bx-2,by+j) - P(bx-1,by+j)| \tag{7}$$

Basically, the inside activity is close to the outside activity. If quantization step becomes wider, the inside activity is increased by the diffusion of quantization error. However, because the flat block does not have texture, quantization error is still small. Therefore, the ratio L is useful to estimate mosquito noise level by next.

$$L(bx,by,n) = \frac{A_m(bx,by,n)}{A_f(bx,by,n)} \tag{8}$$

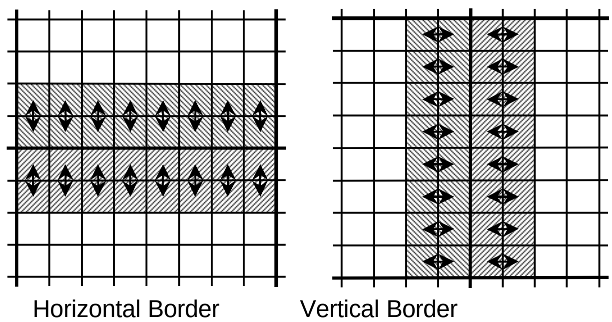


Fig.8 Activity Calculation

4.3 Mosquito Noise Level at a Block

The mosquito noise level of a block BL is shown by (9) with the number of effective side N (1,2,・・,4). N is different by a block.

$$BL(bx,by) = \frac{1}{N}\sum_{n=0}^{N-1} L(bx,by,n) \tag{9}$$

4.4 Mosquito Noise Level at a Picture

If the activity of flat block A_f is very low. Equation (8) gives very high value. To avoid such block, final calculation at a picture uses temporal processing.

4.4.1 Temporal processing

The temporal mosquito noise level of a picture ML_t is given by simple averaging of *BL*.

$$ML_t = \frac{1}{M_t}\sum_{m=0}^{Mt-1} BL(m) \tag{10}$$

Where M_t is the number of mosquito block in a picture. ML_t is the result of estimation. However, in the case of non-degraded picture, they are different each other, and depend on a picture. To get closer values at non-degraded picture, we take additional processing as follows.

4.4.2 Final processing

In the case of non-degraded picture, some block gives very large *BL*. Mosquito noise do not cause very large activity. Therefore, such very large BL may be caused by original picture. And, it is better to reject such block from the estimation.

To decide the block that cause too large *BL*, we use temporal result ML_t. In the final calculation, the block which has the *BL* larger than the double of ML_t is rejected. The number of blocks is also reduced to *M* by the rejection. The final mosquito noise level of a picture is given by next.

$$ML = \frac{1}{M}\sum_{m=0}^{M-1} BL(m) \tag{11}$$

5. CONTROL OF POST FILTER

Final mosquito noise level for each blocks are calculated by multiplication of the B_m and *ML*. Fig.8 shows the structure of adaptive post filtering. The limitation value *C* of non-linear processing NL is given by equation (12). LPF is two-dimensional filter with 7 taps at both horizontal and vertical.

$$C = B_m(bx, by) \times (ML - 1) \times 3.5 \tag{12}$$

If *ML* is closer to 1.0, filter is not used for whole picture. The strength of filter effect depends on both *ML* and B_m. For the non-mosquito blocks, adaptive filter is not applied any time. The proposed method can bring the large noise reduction with minimum side effect.

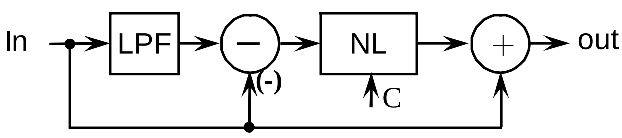


Fig.9 Structure of adaptive post filtering

6. EXAMINATION

6.1 Condition of Evaluation

We use MPEG-4 coding to get a coded pictures. Coding condition is simple profile (N=15, M=1) with default quantization matrix and fixed macro block quantization. Quantization scale is changed to 1 to 15 by step one. In this case, artifacts of decoded picture increase almost linear.

Tested sequences are ITE standard sequences. We use ten sequences which have different type of texture and motion. Fig.10 shows these sequences. They are 720 x 480 pixel / 30fps progressive scanning (1 sec.).

Boy and Toy | Opening Ceremony | Chromakey (Flowers) | Crowded Crosswalk | Driving | Character Pattern | Rotation Disk (1/60) | Soccer Action | Walk through the Square | Weather Report

Fig.10 Tested Sequences

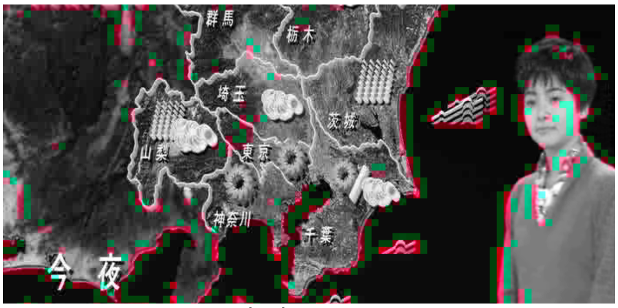
6.2 Estimation of Mosquito Block

At first, we check the estimated mosquito block in Fig.11. The mosquito block ($B_m > 0$) is shown by red color level. Useful flat block B_f is shown by green color. Borders of red and green are useful side for the calculation of activities. We recognize they are almost reasonable position. Fig.12 shows number of used block for estimation. There are 5400 blocks in a picture. It depends on picture. They are generally stable. However, in some sequence, they are changed to depend on Q_scale.

Boy and Toys

Ceremony

Square



Whether Report

Fig.11 Estimated Mosquito Block (B_m)

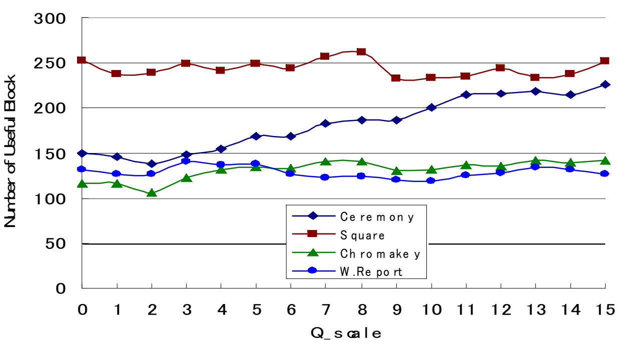


Fig.12 Number of Used Blocks

6.3 Estimation of Mosquito Noise Level

Fig.13 shows the estimated mosquito noise level as the proposal. Q_scale=0 means non-degraded picture. Temporal ML does not start from constant value. However, final ML starts from almost the same value (1.0).

Results for each sequence are almost linear on Q_scale, and, the gains depend on the sequences. However, subjective mosquito noise levels also depend on the sequences. We recognize the results of mosquito noise level are also reasonable.

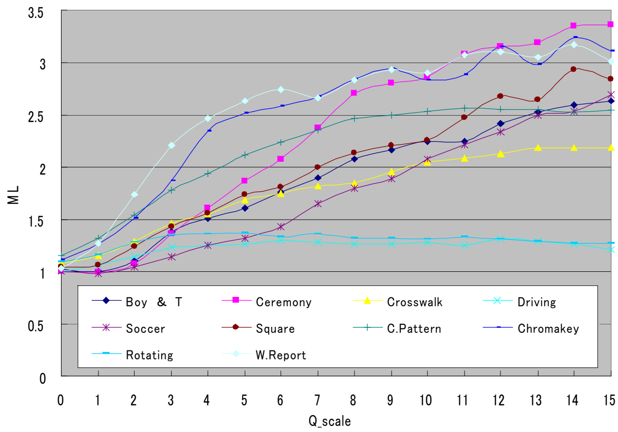
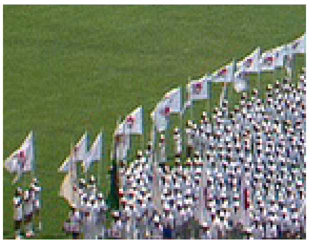


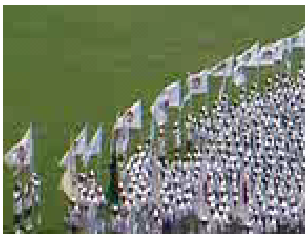
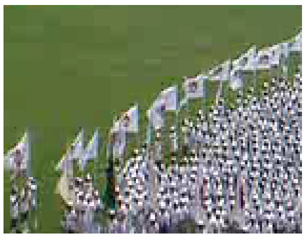
Fig.13 Estimated Mosquito Noise Level

6.4 Control of Post filter

Fig.14 shows pictures of the decoded and post-filtered. The post filter is adapted only when *ML* is high. Therefore, high quality of decoded picture is kept at the picture of Q_scale= 2. The mosquito noise is reduced at the picture of Q_scale= 10.




Decoded (Q_Scale=2) Post Filtered

Decoded (Q_Scale=10) Post Filtered

Fig.14 Example of Post Filtering

7. CONCLUSION

We proposed new objective estimation method of mosquito noise without reference picture. At first, the mosquito blocks are determined by decoded picture. To calculate noise level, the ratio of spatial activity is taken between the mosquito block and neighbor flat block.

As the results of examination with a coding, we recognize the proposed method gives almost reasonable mosquito block and absolute level. Estimation results for each sequence are almost linear on Q_scale.

Next, estimation results are applied for post filter. Adaptive filter is controlled by the estimated mosquito noise level. It is recognized that the high quality of decoded picture is kept and the mosquito noise is reduced effectively at the picture with degradation.

To evaluate the proposed methods more accurately, they should be compared to subjective picture quality.

8. REFERENCES

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