A Novel Video Error Concealment Technique Using Modified Boundary Matching Algorithm with Correlation Function

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***Abstract*—Video transmission over wireless networks becomes a major part of multimedia studies especially after fourth-generation communication standard has been introduced. There is a growing need to improve video visual quality, while its computational complexity should remain low. A low-complexity Error Concealment (EC) method for missing macroblock (MB) recovery is Boundary Matching Algorithm (BMA). Nevertheless, this method suffers from lack of accuracy. In this paper, we propose a novel modified BMA method by exploiting the correlation of the pixels on the edge of the missing MB. The performance of this method is explained in detail and extra experiment results are given to demonstrate its superiority over BMA method.**

I. INTRODUCTION

Highly compressed videos are very susceptible to transmission errors. In addition, inter frames propagate the errors through the subsequent frames. This can degrade the visual quality of the video, drastically. Although the errors cause severe damages to different parts of the video, there are spatial and temporal correlations between different parts of one frame and consecutive ones, respectively. Error Concealment (EC) is a powerful post-processing method among various error protection techniques since it can conceal erroneous MBs without adding any redundancy at the decoder side. Various EC algorithms are discussed in [1], in more details. Achieving a high-performance low-complexity EC method forces us to find a trade-off between visual quality and complexity. There are two types of EC: spatial and temporal. The former uses the correlation between the pixels of the same frame while the latter exploits the correlation between consecutive frames.

One of the useful techniques which is a temporal EC is Boundary Matching Algorithm (BMA). It exploits the information of boundary pixels of the missing MB to find the best possible replicate of it in the previous frame.

The remainder of the paper is written in the following organization. Section II is a brief review of some recent work in this area. Section III is an explanation of BMA technique. In Section IV, our proposed technique is presented in detail. Section V is devoted to experimental results. Finally, conclusions are given in section VI.

II. RELATED WORKS

Although BMA is an attractive method for EC, it is not reliable and sufficient to accurately estimate the missing MB. Therefore, several modifications have been proposed. Yu-Hsuan Lee et al. proposed a Progressive BMA with Euclidean Distance (PBMA) [2]. They exploit the corrupted-residual in order to recover the blocks successively based on the minimizing the impact of the residual using ED. They achieve better EC about 0.1 dB related to the BMA method. Another interesting proposed method is Refined BMA (RBMA). In their paper, they proposed different MVs for different parts of the missing MB. Therefore, they can minimize the difference between missing MB and replacing MB better [3].

Another interesting method is proposed by Zheng et al. [4]. In their paper, they exploit the Lagrange interpolation formula to develop a temporal EC method. They use this formulation to make up a measurement to describe different motion types of the motion vectors (MV).

In this paper, we propose a novel BMA algorithm to estimate the erroneous MB. Also, we enhance the estimation using boundary information of several displacement of the replacing MB in the reference frame. In other words, we develop a correlation function to exploit these boundary information to recover the missing MB more accurately. We show that the proposed method has low computational complexity and there has to be trade-off between quality and complexity if we want to keep the performance high.

III. BOUNDARY MATCHING ALGORITHM

The BMA method recovers missing MB by exploiting adjacent pixel information in two consecutive frames. In other words, the difference between external boundary pixels of the erroneous MB in current frame and the internal pixels of a considered MB in reference frame is used to measure a cost function. The best candidate for the missing MB is achieved when the cost function is minimized [5].

Let $M_t^{i,j}(m,n)$ be the $(m,n)^{th}$ pixel in $(i,j)^{th}$ MB in t^{th} frame where its components are the horizontal and vertical indices, respectively. As it is depicted in fig.1, we consider

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t^{th} and $(t-1)^{th}$ frame as the current and reference frame, respectively. In fig.1, $O(i,j)$ is considered as origin of missing MB in current frame and $O(i+m,j+n)$ is the displaced origin by the $MV(i,j)$. In order to formulate this problem, we define a cost function as in (1).

$$C=\sum_{k=1}^{4}(c_k) \tag{1}$$

Where c_k is Sum of Absolute Differences (SAD) of each side of the erroneous MB and C is the cost function. To formulate c_k for each side of the MB, let $M_{t-1}^{i',j'}(m,n)$ be the candidate MB in $(t-1)^{th}$ frame. Therefore, c_k is defined in equations (3)-(5) which are derived for right, bottom, left and top boundaries of the considered MBs, respectively, for $(i,j)^{th}$ MB.

$$\begin{aligned}
c_1 &= |M_t^{i,j}((i-1)\times 16,(j-1)\times 16+1:j\times 16) && (2)\\
&\quad -M_{t-1}^{i',j'}((i'-1)\times 16+1,(j'-1)\times 16+1:j'\times 16)|\\
c_2 &= |M_t^{i,j}((i-1)\times 16+1:i\times 16,(j-1)\times 16+1) && (3)\\
&\quad -M_{t-1}^{i',j'}((i'-1)\times 16+1:i'\times 16,j'\times 16)|\\
c_3 &= |M_t^{i,j}(i\times 16+1,(j-1)\times 16+1:j\times 16) && (4)\\
&\quad -M_{t-1}^{i',j'}(i'\times 16,(j'-1)\times 16+1:j'\times 16)|\\
c_4 &= |M_t^{i,j}((i-1)\times 16+1:i\times 16,(j-1)\times 16) && (5)\\
&\quad -M_{t-1}^{i',j'}((i'-1)\times 16+1:i'\times 16,(j'-1)\times 16+1)|
\end{aligned}$$

The coordinates of the candidate MB in $(t-1)^{th}$ frame is found when cost function C is minimized. Note that the notation $x:y$ means $x:y=\{x,x+1,\ldots,y-1,y\}$ overall this paper. $V(i',j')$ is the coordinate vector of the replacing MB which is derived in (6)

$$V(i',j')=\arg\min\{C\} \tag{6}$$

IV. THE PROPOSED ALGORITHM

A. BMA accuracy enhancement Using Correlation Function

The correlation function of two signals, X and Y, are defined as $E[XY]$. This function is important because it determines when two signals are linearly related to each other [6]. The simple form of correlation function $R[k]$ for two one dimentional signal is formulated as

$$R[k]=\sum_{n=-\infty}^{+\infty}(I_1[n]I_2[n+k]) \tag{7}$$

Where I_1 and I_2 are the considered signals and k is the time shift between them.

In the video sequences we can consider each frame as a two dimentional signal. Let $I_t^{i,j}[m,n]$ be the $(m,n)^{th}$ pixels in t^{th} frame. Therefore, equation (7) is reformulated in (8) as

$$R[k_x,k_y]=\sum_{m\in A}\sum_{n\in B}(I_t^{i,j}[m,n])I_{t-1}^{i',j'}[m+k_x,n+k_y]) \tag{8}$$

Where k_x and k_y are displaced values in x and y directions, respectively. $R[k_x,k_y]$ calculates the correlation between pixels in the current and previous frames for $(i,j)^{th}$ and $(i',j')^{th}$ MB, respectively. Additionally, A and B are the sets that include the coordinates of the considered frame pixels for horizontal and vertical indices, respectively.

Equation (9) is derived using (8) and the boundary information that we utilize them to calculate the cost function, *i.e.,* (m,n) is adjusted. In other words, A and B are selected from the boundaries exploited (3)-(5).

$$\begin{aligned}
R[k_x,k_y] &=\\
&\sum_{(i,j)\in M}\sum_{(i',j')\in N}(I_t^{i,j}((i-1)\times 16,(j)\times 16+1:j\times 16))\\
&\times I_{t-1}^{i',j'}((i'-1)\times 16+1+k_x,(j'-1)\times 16\\
&+1+k_y:j'\times 16+k_y)\\
&+I_t^{i,j}((i-1)\times 16+1:i\times 16,(j-1)\\
&\times 16+1)\\
&\times I_{t-1}^{i',j'}((i'-1)\times 16+1+k_x:i'\times 16+k_x,j'\\
&\times 16+k_y)\\
&+I_t^{i,j}(i\times 16+1,(j-1)\times 16+1:j\times 16)\\
&\times I_{t-1}^{i',j'}(i'\times 16+k_x,(j'-1)\\
&\times 16+1+k_y:j'\times 16+k_y)\\
&+I_t^{i,j}((i-1)\times 16+1:i\times 16,(j-1)\times 16)\\
&\times I_{t-1}^{i',j'}((i'-1)\times 16+1\\
&+k_x:i'\times 16+k_x,(j'-1)\times 16+1+k_y))
\end{aligned} \tag{9}$$

Where M and N are the coordinates of the MBs in current and reference frame, respectively. Note that the computational complexity of this algorithm depends on the location of the displaced origin in $(t-1)^{th}$ frame. That is, there is only two boundaries when it is located in the corners of the frame or three boundaries when it is located in four edges of the frame. $R[k_x,k_y]$ calculates the correlation between the edges 1 to 4 in frame t and $t-1$ which are shown in fig.1. The higher the values of k_x and k_y are, the wider area around the displaced origin is tested to find the best correlated replacing MB. Therefore, they are important parameters since in the channels with higher Packet Loss Rate (PLR), one can increase them to compensate the BMA inaccuracy. Therefore, the proposed method makes BMA more robust and indestructible against channel errors. This property is tested in section V.

B. Computational Complexity Analysis

Algorithm complexity is an important issue in EC techniques. This problem arises specially when our application is interactive or power consumption is important. To address the issue, we consider E erroneous MBs in a frame. There is 9 comparisons to find where the displaced origin is located. As it has been discussed in section III, the location of the displaced origin is important in computational complexity. Generally, consider it is located in the middle of the frame and all four boundaries are calculated in correlation function, *i.e.,* $R[k_x, k_y]$. There is 16 multiplication for 16 boundary pixels for each side. In addition, there is $k_x \times k_y$ correlation calculated. Therefore, there is $E \times \{(k_x \times k_y) \times (4 \times 16)\} = 64 \times E \times k_x \times k_y$ calculations. Obviously, the complexity of algorithm is depended on k_x and k_y, directly. Consequently, although increasing k_x and k_y can make our method more robust, complexity of the algorithm rises, drastically. Therefore, there is a trade-off between increasing the robustness and decreasing the complexity.

V. EXPERIMENTAL RESULTS

A. The proposed method evaluation

The platform for evaluation of the proposed method is based on QCIF (176×144) pixels video sequences which contain 150 frames. It is based on 30 frames/second and coding structure is "IPP…IPP…". The distance between two I-Frame is 12 and we do not consider B-Frame since they can be easily omitted if they are erroneous. It should be noted that Quantization Parameter (QP) is consistent along the whole sequence coding procedure. The PSNR between two different frames is calculated by (10)

$$PSNR = 10\log_{10}(\frac{B^2}{RMS}) \tag{10}$$

Where B is the largest possible value which is 255 for video sequences and RMS is Root Mean Square between two frames. In our experiment, the measurements are based on Y component of the frames and this YPSNR is calculated in decibel unit.

Fig.3 and 4 are recovered 29^{th} frame of the coastguard sequence. The PLR and QP are 20% and 25, respectively. It is obvious that the proposed algorithm finds the replacing MB accurately. Note that in higher PLR channels the proposed method can recover erroneous MBs more efficient than BMA.

Fig. 5 compares the proposed method and BMA for the whole 150 frames of foreman sequence. Therefore superiority of the proposed algorithm is shown. In Fig. 6, the comparison of the proposed method and Zero MV (ZMV) is depicted. The remarkable ability of the proposed algorithm for finding the best replacing MB is shown in both Fig. 5 and 6 where the proposed method outperforms BMA and ZMV techniques by at least 0.1 and 0.15dB, respectively.

VI. CONCLUSION AND DISCUSSION

In this paper, we attempted to extend a effective method for increasing the accuracy of BMA for recovery of the missing blocks in decoder side. First, we develop a correlation-based algorithm to measure the efficiency of the replacing MB. Hence, replace the missing MB with it. In correlation estimation, we exploit the boundary information of the missing and estimated MB on the basis of different locations of the displaced origin in previous frame. Simulation results show the proposed method yields better visual quality. In addition, we calculate the computational complexity of the proposed algorithm and show that it has low complexity. Additionally, a trade-off between complexity and visual quality has been investigated through the paper which makes it more practical for different applications.

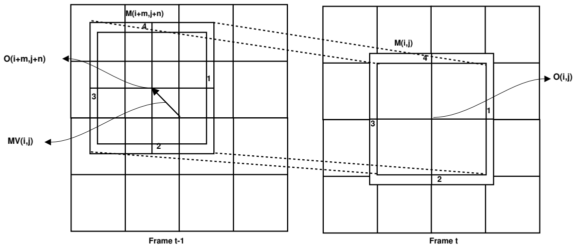

Fig. 1. Summary of BMA method. Frame t and $t-1$ are current and reference frames, respectively. Each individual square is a block. The external and internal boundary pixels in frame t and $t-1$, respectively, are used to generate the cost function.

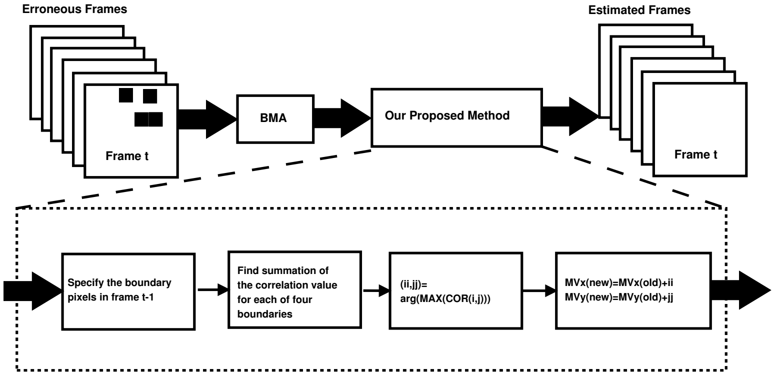

Fig. 2. Summary of the proposed method. At first, the motion vectors for erroneous MBs are derived by BMA method and then our proposed method enhances the accuracy of the motion vectors. The enhancement is achieved using correlation between boundary pixels of the missing MB and displaced replacing MB in previous frame. The highest correlation is selected as a candidate for motion vector recovery.

Fig. 3. Frame 29 of the coastguard sequence. It is recovered by BMA method and PLR=20% and QP=25. The break in the scene shows inaccuracy of BMA method especially in high PLR.

Fig. 4. Frame 29 of the coastguard sequence. It is recovered by the proposed method. PLR= 20% and QP=25. The missing MB is replaced correctly and accurately.

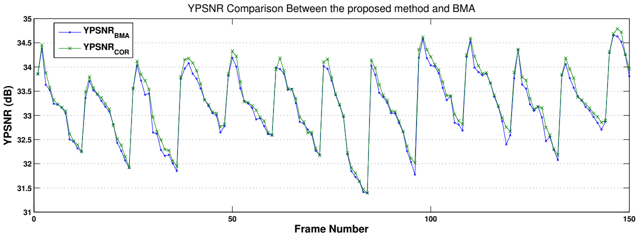

Fig. 5. The YPSNR comparison of each concealed frame for foreman sequence. The proposed method is mostly higher than BMA in most of the frames.

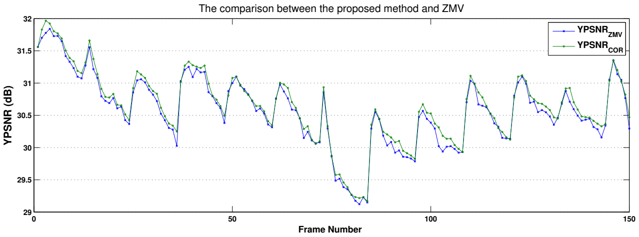

Fig. 6. YPSNR plot of each concealed frame for coastguard sequence. The proposed method is superior in most of the frames.

REFERENCES

[1] Y. Wang, and Qin-Fan Zhu, “Error control and concealment for video communication: A review,” *proc. IEEE,* vol. 86, no. 5, pp. 974-997, May 1998.

[2] Yu-Hsuan Lee and Tsai-Hsing Wu, “Video Error Concealment Using Progressive Block Matching Algorithm with Euclidean Distance”, *Eighth International Conference on Intelligent Information Hiding and Multimedia Signal Processing*, pp. 199-202, July. 2012.

[3] T. Chen, X. Zhang, and Y. Q. Shi, “Error Concealment Using Refined Boundary Matching Algorithm,” *IEEE Trans. Circuits and Systems for Video Technology,* vol. 13, pp. 560-576, July 2003.

[4] J Zheng and L. P. Chau, “A motion vector recovery algorithm for digital video using lagrange interpolation,” *IEEE Trans. on Broadcasting,* vol. 49, pp. 383-389, Dec. 2003.

[5] W. M. Lam, A. R. Reibman, and B. Liu, “Recovery of lost or erroneously received motion vectors,” *in Proc. ICASSSP*, vol. 5, pp. 417-420, 1993.

[6] John. A. Gubner, “Probability and Random Processes for Electrical and Computer Engineers,” *Cambridge University Press*, June 2006.