Temporal Error Concealment Algorithm Using Adaptive Multi-Slice Boundary Matching Principle

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Abstract: On the channel of wireless transmission environment, there is the data loss suffered from a packet loss. A packet loss brings lowering of image quality of the decoded image. Error concealment method is the efficient method that reduces lowering of performance in having error. This study introduces a method of Adaptive Multi-Side Boundary Matching Principle(AMSBM). After carrying out the analysis of an image data about the boundary data of lost block, this method carries out a block matching by judging how much you can use the most confidential data. It presents higher performance than the related method that was researched formerly. It shows an improved performance of 0.36 dB on average than MSBM method that is presenting the superior performance currently.

1. Introduction

The compressed video or image data under wireless transmission environment is strongly related within bit stream. Then, the signal of compressed video has affect of network disorder and channel noise by physical network channels including wire/wireless network. Therefore, on the channel of wireless transmission environment, a packet causes to be lost.

A packet loss means that data of image or video data will be useless data by a loss or distortion. For a method to prevent this kind of transmission error, there is a technique that conceals lost block with received data[1]~[2].

There are largely two methods. One is to conceal error in spatial domain and the other is to conceal error in temporal domain. For the method to conceal error in spatial domain, there is the method that recovers using data that doesn't have affect of error of lost block's boundary[3].

Meanwhile, the method that conceals error in temporal domain is the method that uses the previous frame data much similar to the current frame[4]. You can conceal error by finding similar block to lost block in the previous frame.

Among the researches about temporal error concealment method that is researched till now, temporal error concealment using multi-side boundary matching principle carries out error concealment using reference block data of two close boundary in error.

It shows higher performance because it conceals lost block using more boundary data than the former researches. However, if the block that was incorrectly recovered is used with reference block, another error is propagated because it carries out block matching by selecting fixed position of boundary block to reference block. This will be a cause of not only subjective lowering of image quality, but also objective lowering of image quality. Therefore, the proposed method is the method that carries out an examination of boundary conformity, investigates the confidentiality of the block and decides the position and size of reference block adaptively. It can reduce the lowering of performance during to the propagation of existing error.

2. Temporal error concealment algorithm using multi-side boundary block matching

MSBM is the temporal error concealment method[5]. MSBM uses the boundary data as a reference data and conducts block matching in the reference frame. The best matching data in reference frame has the smallest SAD(sum of absolute different).

When error occurs, there are MB (MB) type errors, it divides one lost MB into 4 sub-blocks(8x8 block). According to the available boundary data, the location of the reference boundary can be different. 2.1 chapter illustrates the method when a single block error occurs. 2.2 chapter illustrates the method when a single-slice error and a multi-slice error occur which the result as the consecutive MB error.

2. 1 Sub-block matching algorithm for a single block error

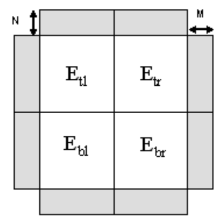

Figure 1. Rows and columns used in block matching principle

A corrupted MB is divided into four sub-blocks as shown in Fig. 1. E_{tl}, E_{tr}, E_{bl}, E_{br} are the divided sub-blocks at different location, respectively. The nearest adjacent N rows and M columns pixels of the MB are used to find the best block to recover the MB. In case of a single block error, every boundary data is available. The search ranges are set to be 15 herein, and the full search (FS) is used to evaluated all possible candidate blocks within the search range.

The best sub-block to recover a lost one is determined by the minimum sum of absolute difference (SAD). For the four sub-blocks, their SADs are calculated by the following equations:

$$SAD(E_{tl}) = \sum_{j=-N}^{-1}\sum_{i=0}^{7}\left| E_{tl}(x+i, y+j) - E_{tl}^{'}(x+dx+i, y+dy+j)\right| + \sum_{j=0}^{7}\sum_{i=-M}^{-1}\left| E_{tl}(x+i, y+j) - E_{tl}^{'}(x+dx+i, y+dy+j)\right| \quad (1)$$

$$SAD(E_{tr}) = \sum_{j=-N}^{-1}\sum_{i=0}^{7}\left| E_{tr}(x+i, y+j) - E_{tr}^{'}(x+dx+i, y+dy+j)\right| + \sum_{j=0}^{7}\sum_{i=8}^{7+M}\left| E_{tr}(x+i, y+j) - E_{tr}^{'}(x+dx+i, y+dy+j)\right| \quad (2)$$

$$SAD(E_{bl}) = \sum_{j=8}^{7+N}\sum_{i=0}^{7}\left| E_{bl}(x+i, y+j) - E_{bl}^{'}(x+dx+i, y+dy+j)\right| + \sum_{j=0}^{7}\sum_{i=-M}^{-1}\left| E_{bl}(x+i, y+j) - E_{bl}^{'}(x+dx+i, y+dy+j)\right| \quad (3)$$

$$SAD(E_{br}) = \sum_{j=8}^{7+N}\sum_{i=0}^{7}\left| E_{br}(x+i, y+j) - E_{br}^{'}(x+dx+i, y+dy+j)\right| + \sum_{j=0}^{7}\sum_{i=8}^{7+M}\left| E_{br}(x+i, y+j) - E_{br}^{'}(x+dx+i, y+dy+j)\right| \quad (4)$$

Where x,y are the most top and most left position of the lost sub-block in the current frame, dx and dy are the displacement between the lost sub-block in current frame and the candidate sub-block in the reference frame. N and M are fixed to 3 in MSBM method. The sub-block E_{tl}, E_{tr}, E_{bl}, E_{br} is recovered by the sub-block with the minimum SAD from (1),(2),(3),(4), respectly.

2.2 Sub-block matching algorithm for slice errors

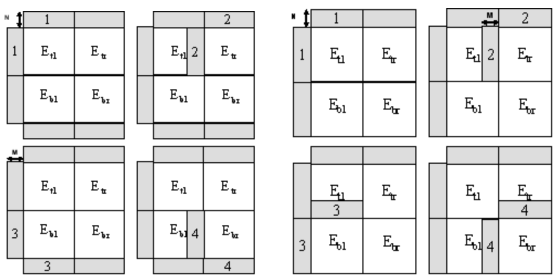

Figure 2. MSBM error concealment algorithm for single-slice (left) and for multi-slice (right)

In the case of a single slice error and a multi-slice error, every boundary data can not be available such like the case of a single block error. Fig. 2 depicts the error concealment method according to each error pattern.

In the case of a single slice error, first, E_{tl} and E_{tr} are concealed in a row. MSBM conducts multi-side block matching using N rows and M columns. The best sub-block to recover a lost sub-block is determined by the minimum SAD using (1). Then, E_{bl} and E_{br} are concealed using the down and left data of lost sub-block instead of up data and left data. The best sub-block to recover a lost sub-block by the minimum SAD using (3).

Int the case of multi-slice error, E_{tl}, E_{tr}, E_{bl} and E_{br} are concealed in a row. In this step, to find best sub-block, it uses the up data and left data of a lost sub-block. It conducts block matching using (1).

3. Proposed method

In case of having a single slice error, MSBM conceals lost blocks by the unit of a MB sequentially. Because the type of a single slice error has sequential MB error. In case of two upper blocks, MSBM uses up and left boundary data regularly. In case of below two blocks, it uses down and left boundary data regularly.

Because this kind of error has the sequential MB error, successively concealed blocks should be correctly recovered. When MSBM conceals a previous MB, the concealed data is recovered by using conducting block matching in the reference frame. The concealed data is not original image data. It is artificial for the high visual quality. However, if this data is not concealed correctly, the effect of this data can propagate error to the following MB.

Therefore, the proposed method decides if you use the boundary data as the reference data after examining a confidentiality of the previous concealed block. According to the decision, it makes error concealed without error propagation at maximum by changing the size of block.

The chapter 3.1 explains the examination of the adaptive block conformity of boundary data. And the chapter 3.2 explains the decision method of position and size of variable block by the boundary conformity degree.

3. 1 Examination of adaptive block conformity of boundary data

There is the method that determines the edge orientation at the boundary of the lost block and then decides which boundary signal to use in estimating the lost block [6]. However, it didn't offer an adaptive threshold value. It cannot perform the examination of conformity at each boundary, respectively. In this paper, we propose the advanced examination method.

Fig. 3 depicts the proposed method in recovering E_{tl} with error. This step is the first step examination of adaptive block conformity of boundary data. Here, considering a single slice error, the useful boundary data is up and left boundary data. The left data was concealed in previous MB and the up data is error free data in a single slice error type. Before concealing the sub-block E_{tl}, it conducts the examination of block conformity of boundary data.

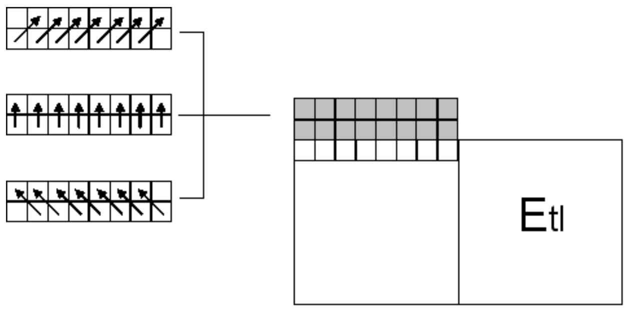

Figure 3. Boundary matching degree examination step 1 for single slice

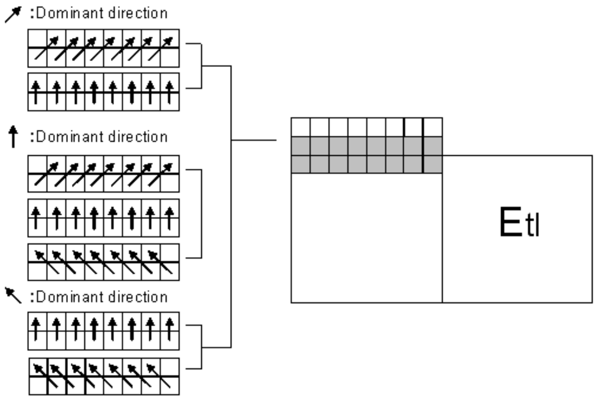

Figure 4. Boundary matching degree examination step 2 for single slice

Before concealing the current loss sub-block, it conducts the examination of block conformity of error free data 8x2 pixels which is located on above data of the left sub-block. The examination cost functions of block conformity according to each direction are (5)(6)(7), respectively.

$$Dr = \frac{1}{N-1}\sum_{i=0}^{N-2} \left| X(x+i,y) - X(x+i+1,y-1) \right| \quad (5)$$

$$D_v = \frac{1}{N}\sum_{i=0}^{N-1} \left| X(x+i,y) - X(x+i,y-1) \right| \quad (6)$$

$$D_l = \frac{1}{N-1}\sum_{i=1}^{N-1} \left| X(x+i,y) - X(x+i-1,y-1) \right| \quad (7)$$

Dr is a cost function that is applied in oblique edge direction and Dv and DI shows the cost function for each vertical and inverse oblique line direction. Also, x,y shows the position of the bottom line's first pixel among pixel line to examine boundary conformity and here, it is the most bottom line's first pixel of above sub-block of left sub-block.

Using these cost functions, you can gain the cost function's result value for each direction. It decides a direction with the most minimum value into the dominant direction of boundary and fixes that result value into the result value R for the dominant direction. The result value R is used as a standard value that is compared with result values after then.

If the dominant direction is decided, a cost functions are conducted to the similar directions under a pixel according to the dominant direction. If an oblique direction was decided into the dominant direction, cost functions are conducted in an oblique and a vertical direction. If an inverse oblique direction was decided into the dominant direction, cost functions are conducted in a vertical and an inverse direction. If a vertical direction was decided into the dominant direction, cost functions are conducted under a pixel for oblique, vertical and inverse oblique direction.

According to the dominant direction, it gains the difference value between result value R from the below 8x2 pixels and the result values of cost functions from the below pixels. For example, if the dominant direction is decided to the oblique direction on the upper pixels, it applies the cost functions to the oblique direction and vertical direction at the below pixels. And then, we can gain two difference values. One is the difference value between the result value R and the result value of oblique direction. The other is the difference value between the result value R and the result value of vertical direction.

Among the difference values, if there is a smaller value than predefined threshold T, the boundary of this sub-block is judged to be well concealed and if there isn't a smaller value than predefined threshold T, the boundary of this sub-block is not judged to be well concealed. The predefined threshold T is fixed as the most suitable value by an experiment and we experimented by fixing 4 in this paper.

Also, for sub-block Ebl below Etl, it examines the boundary conformity degree with the same method. Then, instead of examining conformity degree about above pixels of left sub-block, it examines about lower pixels of left sub-block. In case of a single slice error, the below data that is error free can make judge if sub-block was correctly recovered through comparison with concealed image values. Therefore, for concealing the sub-block Ebl, it examines boundary conformity degree with the same method that carried out on the upper. Also, the proposed method can conceal with more accurate data by carrying out each boundary conformity degree in recovering Etr and Ebr.

3. 2 Decision method of variable block position and size by boundary conformity degree

With the process of 3.1, we can judge a confidentiality about the pixels that is on left boundary of the sub-block that will be recovered. This method decides which position's boundary data it uses to recover lost sub-block according to the result of confidentiality.

If we judge the left boundary data has confidentiality, it recovers lost sub-block with existing method. However, if it is judged that left boundary data has no confidentiality, we refer only the up boundary data. We solve the guarantee matter of exact reference data by referring more pixel data from the above block. We can check through block diagram of the total method in figure 5. Here, N value is 6

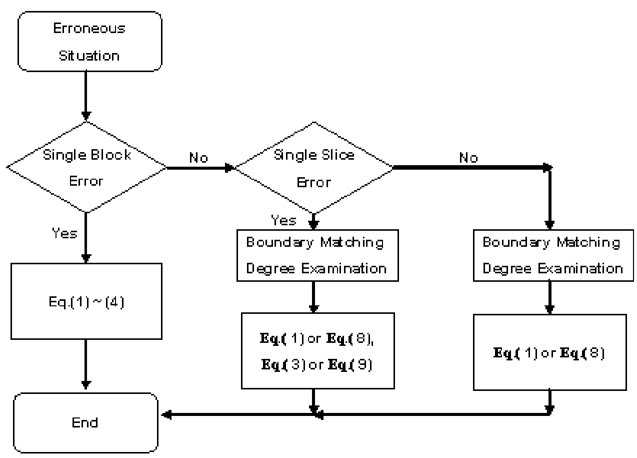

Figure 5. Flowchart of proposed method

$$SAD(E_{tl})=\sum_{j=-N}^{-1}\sum_{i=0}^{7}\left| E_{tl}(x+i,y+j)-E_{tl}^{'}(x+dx+i,y+dy+j)\right| \quad (8)$$

$$SAD(E_{bl})=\sum_{j=8}^{7+N}\sum_{i=0}^{7}\left| E_{bl}(x+i,y+j)-E_{bl}^{'}(x+dx+i,y+dy+j)\right| \quad (9)$$

4. Experiment & result

Four test images were used to compare objective quality of MSBM method with the proposed method. For test image, Football, Foreman, Stefan and Silent were used. We applied to H.264 reference software (JM 10.2) and used 100 frames that coded with I frame frequency 3 and inserted the block loss to only P frame.

The table 1 shows each different MB loss rate and result by test sequence kind. It shows average PSNR of each frame in concealing error with each method after losing MB randomly to 5%, 10%, 15%, 20% on frame except for the first page of each test sequence. Therefore, it has a structure that uses by referring concealed image of the former page in the following frame.

We can see the proposed method has higher performance than MSBM in every test sequence. It means the proposed method shows higher performance in terms of not only subjective image quality, but also objective image quality.

TABLE 1. Simulation results for different MB loss ratios

Test Sequence	PSNR (dB)	MB Loss Ratio			
		5%	10%	15%	20%
Football	MSBM	34.809	30.484	27.868	25.959
	AMSBM	35.470	31.134	28.447	26.185
Foreman	MSBM	41.638	35.992	32.021	29.078
	AMSBM	42.250	36.378	32.364	29.114
Stefan	MSBM	36.600	32.069	29.162	27.024
	AMSBM	37.178	32.565	29.506	27.160
Silent	MSBM	48.071	40.692	35.163	31.188
	AMSBM	48.073	41.036	35.321	31.281

5. Conclusion

In this paper, the proposed method that uses examination conformity degree brings better performance by using adapted image reference pixels that considers edge direction between boundaries. As the result, we can remove error propagation that causes in error concealment and it brought largely improved performance in terms of subjective image quality and also showed better performance on every test sequence in the PSNR part that shows objective image quality.

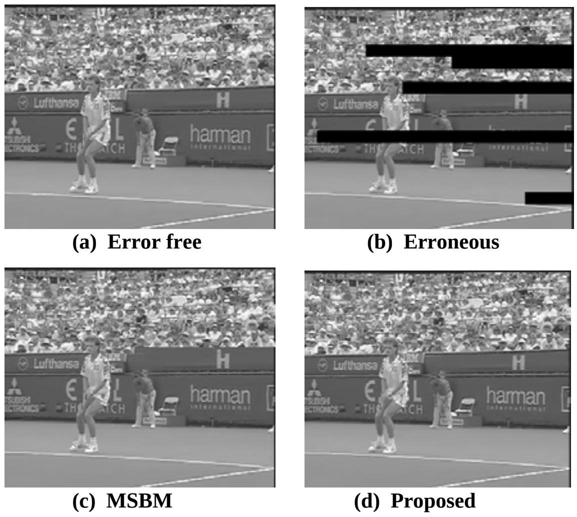

Figure 6. Frame #56 of the Stefan : (a) Error free, (b) Erroneous, (c) MSBM, (d) Proposed

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