Novel Error Concealment Method With Adaptive Prediction To The Abrupt And Gradual Scene Changes

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ABSTRACT

In this paper, the impact of the scene change on the conventional error concealment method is addressed and a novel error concealment method is proposed to improve the insufficiency of conventional temporal error concealment algorithm due to the occurrence of scene change. Combining with the low complexity scene change detection algorithm using macroblock type information, the corrupt blocks resulting from bit errors are concealed either temporally or spatially depending on whether or not an abrupt scene change is found. In the case of gradual scene change, a novel error concealment method of interpolation and extrapolation is proposed to utilize the linear property of gradual scene change sequence, and effectively reduce the concealment error in comparison with the conventional algorithm. Great improvement about 3 to 5 dB PSNR is obtained with only little overhead memory and computation.

1. INTRODUCTION

The MPEG video coding standard is widely used to handle the fast growing video data. Besides reducing the storage space, the smaller amount of compressed video data also facilitates the video communication. As the rapid development of wireless communication and broadband integrated services digital network (B-ISDN), the compressed video transmission technique becomes an urgent work. Although MPEG greatly reduces the video data amount and makes video communication possible, MPEG coding scheme also produces some annoying side effects to practical application. Under the noisy channel, such as the environment of wireless communication, high bit error rate will do great harm to quality of decoded MPEG video due to the error propagation effect of the prediction coding. In addition, under the asynchronous transfer mode (ATM) environment, video data packets may be dropped or lost owing to the congestion in an excessive traffic on the network. The error block produced by loss packets propagates all the group of pictures (GOP) and probably result in unacceptable decoded results. Consequently, being aware of the error source and adopting some proper action to handle the transmission errors become a very important issue. The error block would propagate all the remaining frames of the GOP and greatly degrade the quality of decoded video. As a result of avoiding error propagation, several error concealment algorithms are proposed to compensate corrupt blocks. Most related researches concerning error concealment utilize the temporal correlation of neighboring frames under the assumption that neighboring frames have very similar contents. The simplest and straightforward idea, called block replacement error concealment (BREC), is replacing the lost MB with the co-located MB of the previous decoded frame. The great advantage of this method is that no overhead computation and memory is needed. However, this approach only works for the pictures where there is little or no motion. It is not efficient for fast movements resulting from panning or fast moving objects. For the panning sequence like the well-known "windmill", BREC algorithm would produce annoying blocky effects resulting from the visible shift. Consequently, in order to track the motion and exploit the high correlation of the motion vectors between adjacent MBs, motion-compensated error concealment method is proposed. Motion compensated temporal error concealment (MCTEC) [8] tries to estimate the motion vectors of corrupt blocks, based on which, corrupt blocks can be compensated.

Although satisfactory error concealment results are achieved, many researches are still in progress to find the best motion vector estimation for corrupt MB and the best concealment policy to handle different frame types. In this paper, an unnoticed error propagation problem resulting from the occurrence of scene change is pointed out and the insufficiency of conventional algorithm to deal with the problem is discussed, hence a novel and improved error concealment strategy is proposed. The impact of scene change on error concealment is illustrated in Fig. 1. Combining with the scene change detection algorithm based on MB type information [10], this novel algorithm lead us to make the better choice of which reference frame to predict and conceal the error, either spatial or temporal error concealment should be adopted and whether interpolation and extrapolation are needed. For the abrupt scene change, the corrupt MBs of the nearest following P frame right after the scene change should be spatial error concealed because this P frame has no temporal correlation with the anchor P or I frame at all. Furthermore, for the B frames, the corrupt blocks should be temporal concealed with the anchor P or I frame at the same shot. In addition to the abrupt scene change, some strategies are also proposed for the gradual scene change, which are usually created by the dissolve effect. The more accurate interpolated and extrapolated error concealment algorithm can help us to reconstruct the corrupt blocks more effectively. Based on the linear property of dissolve sequence, the corrupt blocks of B frames can be concealed by the interpolation of two anchor frames. As well, the corrupt blocks of P frame can be concealed by the extrapolation of former two anchor P or I frames or by the interpolation of two adjacent anchor P or I frames. Certainly, the parameter of interpolation or extrapolation should be estimated in advance from the complete decoded block groups. Simulation results show that great improvement is obtained in comparison with the conventional temporal error concealment algorithm.

Proposed Method

Before introducing the proposed error concealment method, we first introduce the GOP structure used in this paper. The GOP structure shown in Fig. 2 would makes our description easier. Besides, the scene change detection adopts the methods from our previous study [10].

Strategy for the abrupt scene change

For simplicity, our method is divided into two parts: error concealment in the P frame and error concealment in the B frame. For P frames, only one anchor P or I frame exists. When an abrupt scene change involved in a SGOP, there is totally no temporal correlation between Pr and Pf and, once the bit error occurs, the temporal error concealment is no longer adequate. The only remaining choice is spatial error concealment though it is not very satisfactory in performance. Compared with zero temporal correlation between Pr and Pf, however, the spatial correlation between the corrupt MB and the adjacent MBs is more significant. In our algorithm, once the scene change is detected, the error concealment mechanism of Pr is switched from temporal to spatial mode. In our method, the weighted interpolation method [8] is utilized for spatial error concealment. As to the error concealment of B frames, the prediction direction for concealment of corrupt MBs is decided explicitly according the scene change location. Clearly, the corrupt MB of the B frame in scene change SGOP should temporally concealed by the anchor frame, either an I or P frame, which belongs to the same shot because the temporal redundancy still exists. Fig. 3 illustrates the strategy of error concealment of the proposed algorithm.

In addition, the error propagation due to the scene change stops as the GOP ends. When I frame of the next SGOP is decoded, the impact of scene changes on error concealment is released. This nature introduces a better error concealment mechanism on the last SGOP of the GOP involving an abrupt scene change. The I frame belonging to the next GOP can provide a better reference for concealment. Theoretically, the last P frame of the GOP, which involves an abrupt scene change, is poor in quality because of the unsatisfactory performance of spatial error concealment and the error propagation. A remedy is proposed by marking the corrupt regions where spatial error concealment is applied, and compensating this region of the last P frame with the refreshed I frame. This strategy provides a solution to relieve the impact of the scene change on the last SGOP. For the purpose of easy implementation and low computation complexity, the motion vectors of the re-prediction adopt the inverse motion vectors of the marked MBs under the assumption that the motion is linear in the time axis.

Strategy for gradual scene change

The gradual scene change resulting from dissolve effect takes a sequence of frames to switch from one scene to another. Within the gradual scene change sequence, the temporal correlation is less significant and the temporal error concealment is not practical. To handle this problem, we introduce a novel extrapolation and interpolation error concealment (EIEC) algorithm. The gradual scene change detection algorithm acts as an initial step toward EIEC algorithm. In our method, the dissolve sequence is detected once the ratio of interpolative MBs exceeds a pre-defined threshold in the potential SGOP where Pr has significant number of Intra-coded MBs. In the first SGOP involved in the dissolve sequence, the corrupt MBs of Pr are still applied the temporal error concealment. However, some improvement can be made on the error MBs of B frames since there are two possible reference frames. Based on the interpolation property of dissolve sequence, the mathematical relation between Pf, Br and Pr should follows:

$$B_f = x_B \cdot P_f + (1 - x_B) \cdot P_r \qquad (1)$$

where x_B is the parameter of interpolation and can be calculated by the following Eq (2):

$$x_B = \frac{1}{N} \sum_{B_{fi} \in B_{fc}, P_{ri} \in P_{rc}, P_{fi} \in P_{fc}} \frac{B_{fi} - P_{ri}}{P_{fi} - P_{ri}} \qquad (2)$$

where P_{fc}, P_{rc} and B_{fc} represent the region where no error MB occurs on all three frames and N represents the number of the total pixels of the region. Applying the parameter x_B and the property of interpolation, the corrupt MBs can be concealed using Eq (1). By contrast, conventional temporal error concealment is not sufficient for handling the gradual scene change because neither Pr nor Pf alone is suitable for concealment.

Concerning the error concealment of P frames, a more complex algorithm is proposed. A group of P frames, denoted as Pn-1,Pn and Pn+1, across two adjacent SGOPs involved in the gradual scene change also follows the property of linearity. As a result, similar to B frames, the parameter x_P of interpolation can be found from Eq (5) and applied to error concealment.

$$P_n = x_P \cdot P_{n-1} + (1 - x_P) \cdot P_{n+1} \cdots\cdots\cdots\cdots (3)$$

$$P_{n+1} = \frac{1}{1 - x_P} \cdot P_n + \frac{x_P}{1 - x_P} \cdot P_{n-1} \cdots\cdots\cdots\cdots (4)$$

$$x_P = \frac{1}{N} \sum_{P_{ni} \in P_{nc}, P_{(n+1)i} \in P_{(n+1)c}, P_{(n-1)i} \in P_{(n-1)c}} \frac{P_{ni} - P_{(n+1)i}}{P_{(n+1)i} - P_{(n-1)i}} \cdots\cdots (5)$$

For error MBs of Pn+1, extrapolation from Pn-1 and Pn by Eq (4) can provide very adequate concealed MBs. On the other hand, however, the interpolation of Pn+1 and Pn-1 by Eq (3) to conceal the error MBs of Pn is not so effective because the error of Pn will propagates to Pn+1. Fortunately, the significant ratio of Intra-coded MBs of Pn+1 provides some refreshed MBs co-located with the error MBs of Pn. It makes interpolation error concealment at the MB, where Intra-coding applied in Pn+1, become valid. The EIEC algorithm is illustrated in Fig. 4.

EXPERIMENTAL RESULTS

In order to examine the performance of the proposed method, 127 scene change sequences in SIF format are encoded at the bit rate of 4Mbps. For each test sequence, three methods, which include BREC, MCTEC and the proposed algorithm, are simulated and compared. For each sequence and some selected Block Error Rate (BER), 100 simulations are made and the average PSNR is obtained. Simulation results of several clips of video sequences containing 127 scene changes are shown in Table 1 and Fig 5, and about 3 to 5 dB in PSNR is gained corresponding to different BER. In all the experiments, it is worthwhile to emphasize that only the GOP with a scene change is taken into consideration and PSNR calculation. It is because the error resulting from poorly concealed block due to the scene change will not propagate to next GOP. For gradual scene changes, the simulation results are shown in Table 2 and Fig. 6. In these experiments, 25 dissolve sequences, 5 to 25 in length and 1 to 2 GOPs involved, are tested. Significant improvement about 3 dB is made by EIEC.

Table1: The Comparison of different methods for abrupt scene changes

BER	No Error	BREC	MCTEC	Proposed
0.5%	36.56	31.45	31.84	34.85
1%	36.56	28.85	29.35	33.01
2%	36.56	25.25	26.34	30.72
3%	36.56	23.21	24.32	27.55

Table2: The Comparison of different methods for gradual scene changes.

BER	No Error	BREC	MCTEC	Proposed
0.5%	35.03	31.81	31.40	33.07
1%	35.03	29.81	29.66	32.12
2%	35.03	26.64	26.30	29.41
3%	35.03	24.99	24.63	27.96

CONCLUSIONS

In this paper, a novel error concealment algorithm is proposed to deal with the error propagation from scene change and the insufficiency of the conventional algorithms. Once the scene change occurs, either abrupt or gradual scene change, the change of the scene contents will cause the conventional temporal error concealment algorithm to replace the corrupt blocks with reference blocks with less or even no temporal correlation. It creates significant concealment error and the error will propagate to all GOP. Our method provides a solution to provide better concealment results. Simulation results show that significant improvement about 3 to 5 dB PSNR gain is obtained when compared with conventional temporal error concealment algorithm.

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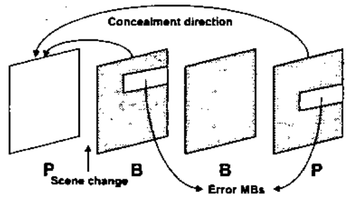

Fig 1: The impact of scene change on error concealment.

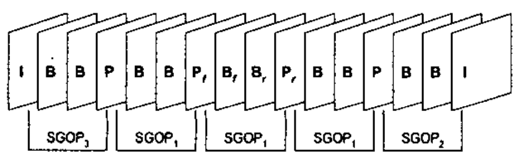

Fig 2: The GOP and SGOP structure used in this paper

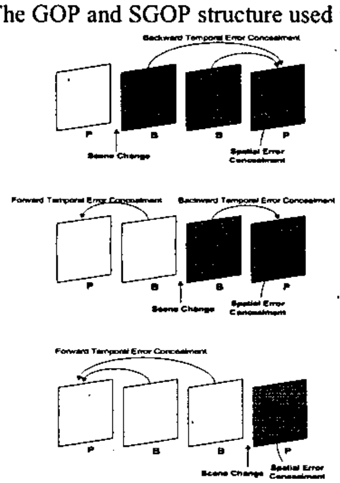

Fig 3: The proposed concealment method for abrupt scene change.

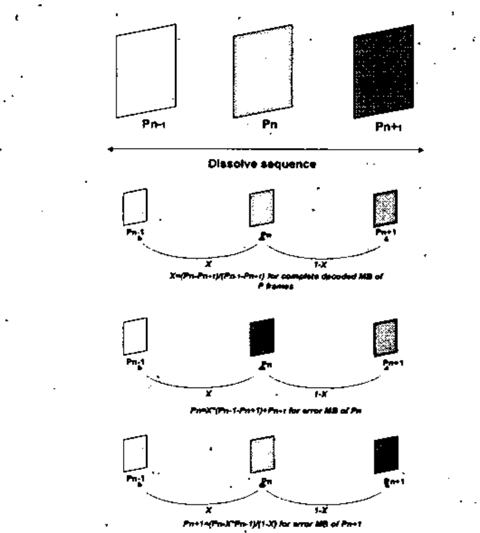

Fig. 4: An illustration of interpolated and extrapolated temporal error concealment to handle dissolve sequences.

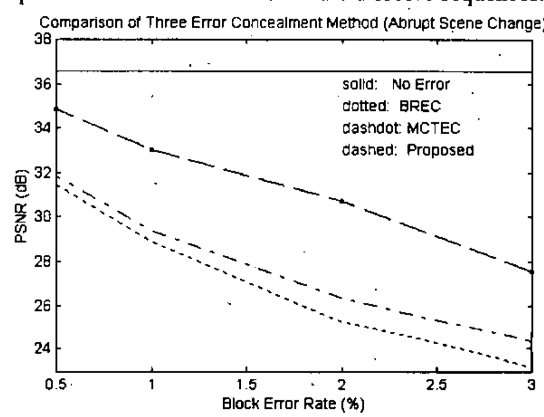

Fig 5: The plot of comparison of three methods (Abrupt scene change)

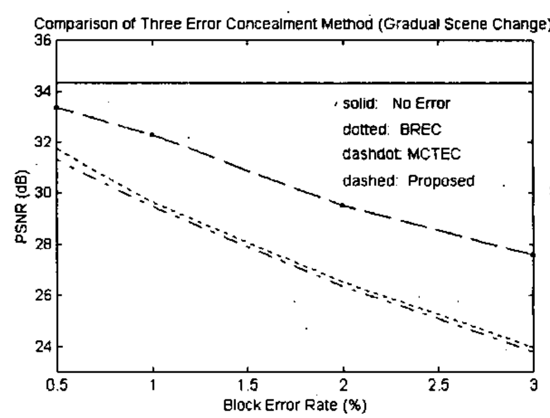

Fig 6: The plot of comparison of three methods (Gradual scene change)