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Error Concealment Used for P-Frame on Video Stream over the Internet

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Abstract: Error concealment on the end of decoder, which makes use of the correctly received video data to conceal the lost video, does not need any redundancy data and has no impact to bandwidth of network. A new concealment method based on multiple motion predictions is proposed here. In this paper, motion vectors in the past and/or future frames are used to achieve the current motion vectors when the current frame is suffered, so the lost parts can be reconstructed. Experimental results show that the performance of the new method is superior to traditional single or dual forward prediction error concealment.

Key-Words: motion vector；error concealment；video stream；Internet

1 Introduction

Compressed video stream is very sensitive to packet loss in the Internet, due to variable length coding(VLC) and interframe prediction coding, which cause spatial and temporal error propagation. As a consequence, the research on error concealment is an important challenging task. On the end of decoder, error concealment technique makes use of the correctly received video data to conceal the lost video.

In the late years, the investigated concealment methods can be categorized into two main areas: intraframe and interframe[1]-[5]. In intraframe concealment, the corrupted parts of the frame are interpolated from either the surrounding pixels or their transform coefficients, of the same frame. To interframe concealment, the lost parts are reconstructed from either the previous uncorrupted frames or their motion vectors. In this paper, a new interframe concealment method based on multiple predictions is presented to conceal the missing motion vectors for P-frame.

The paper organization is as follows. In Section 2, channel characteristics of Internet are reviewed. The new concealment method is introduced in Section 3. Experimental results are presented in Section 4. Finally, the conclusion is stated in Section 5.

2 Characteristics of Internet

2.1 Characteristics Of Internet and Gilbert Channel Model

Some conclusions about the packet loss characteristics over the Internet are drawn in Ref.[6] as follows: no bit errors in IP/UDP packets; no relationship between the packet loss rate, the packet size and the bitrate; packet losses randomly or in very short bursts like two or three packets; packet loss rates dependent on the connection and the time of day.

Channel characteristics of Internet determine the probabilities that packets can be received correctly.

The packet loss behavior is always explained well with a 2-state Markov Chain, i.e., the Gilbert model shown in Fig.1[7]~[8]. State 1 represents a packet loss and State 0 represents the case where packets are correctly transmitted. Two parameters, p and q, are used to characterize the model, where p is the probability of going form State 0 to State 1, and q is the probability of going from State 1 to State 0. Here, p+q does not necessarily equal 1. Different values of p and q define different packet loss conditions that can occur on the Internet. The probability that n consecutive packets are lost is $p(1-q)^{n-1}$. If (1-q)>p, the probability of losing a packet is greater after having already lost a packet than after having successfully received a packet: this is generally the case on Internet video transmission where packet losses occur as bursts. When p and q are fixed, the mean number of consecutive packets lost can be easily calculated and is equal to p/q^2.

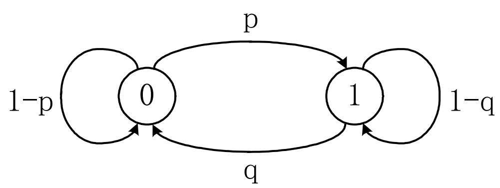

Fig.1 Gilbert model

2.2 Structures of IP Packet and Video Packet

The structures of IP packet and video packet are shown in Fig.2. The size of video packet is limited to prevent the packet fragmentation by the default maximum transmission unit (MTU), i.e., 576 bytes, where the overhead is 50-bytes long. It is clear that the use of large packet size will reduce the total number of generated packets and overhead. So, the video packet approach adopted by MPEG-4 uses periodic resynchronization markers throughout the bitstream[9]~[10]. The length of the video packet is not based on the number of MBs(Macroblocks), instead of on the number of bits contained in that packet.

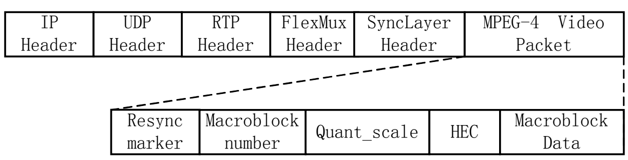

Fig.2 Structures of IP packet and video packet

3 Concealment used for P-Frame

A concealment method, called as Dual forward prediction concealment, is proposed in Ref.[5]. The final prediction frame is obtained by averaging the two previous prediction frames when the two frames are not corrupted. When either of previous prediction frames is corrupted, the final frame copies directly with the one correct prediction frame. Obviously, the method only considers the past reference frames, and ignores the same important relativity between the current frame and the future frames. Furthermore, when transmission conditions in the Internet are too bad, it is possible that the two previous prediction frames are lost; so the above method is invalid.

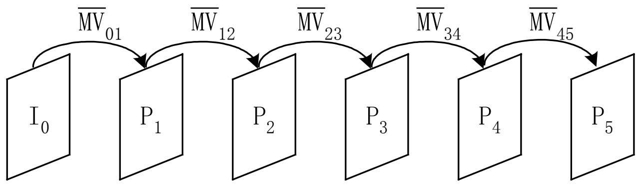

Fig.3 Directions of motion vectors

Fig.3 shows the directions of motion vectors in video sequence. Referring to the previous I-frame or predicted P-frame, the current P-frame is reconstructed by using motion compensation and prediction. Firstly, there are strongly relativities among most of video sequences, and the motion vectors of neighbor frames are similar. Therefore, not only the past prediction frames but also the future prediction frames can be used to conceal the discard parts of the current frame. Secondly, the trend of motions of objects in video sequences can be better estimated by using the motion vectors of multiple frames than of single one. Thirdly, due to the motions of objects in video sequence are coherent, the closer the distance of the two prediction frames is, the less the difference between the corresponding vectors is. Lastly, in packet switched network, video packets are out of order when arriving on the end of decoder. Consequently, the decoder always has capability of buffering and reordering, which makes possible that several prediction frames can be stored.

As stated above, a new interframe concealment used for P-frame is proposed on condition that I-frame is uncorrupted. According to the different relativities between the current prediction frame and the past and/or future prediction frames, several appropriate motion vectors are selected from the received past and/or future candidate vectors based on certain strategies. The new concealment is described by taking $\overrightarrow{MV_{34}}$ in Fig.3 for example. Here, assuming $\overrightarrow{MV_{34}}$ is lost, i.e. Frame P4 is corrupted. Taking storing capacity and computing complexity of the decoder into account, four motion vectors are regarded as candidate vectors: $\overrightarrow{MV_{01}}$, $\overrightarrow{MV_{12}}$, $\overrightarrow{MV_{23}}$ and $\overrightarrow{MV_{45}}$. Due to random packet loss, either all or some of candidate vectors are received. The principle of choosing vectors is to select the ones that are closer to $\overrightarrow{MV_{34}}$ as possible. As a consequence, the following strategies are used to determine candidate vectors:

Strategy 1: choosing $\overrightarrow{MV_{23}}$ and $\overrightarrow{MV_{45}}$ when all candidate vectors are received

$$\overrightarrow{MV_{34}} \leftarrow 1/2\ (\overrightarrow{MV_{23}} + \overrightarrow{MV_{45}}) \qquad (1)$$

Strategy 2: choosing $\overrightarrow{MV_{12}}$ and $\overrightarrow{MV_{45}}$ when $\overrightarrow{MV_{23}}$ is not received

$$\overrightarrow{MV_{34}} \leftarrow 1/3(\overrightarrow{MV_{12}} + 2\overrightarrow{MV_{45}}) \qquad (2)$$

Strategy 3: choosing $\overrightarrow{MV_{12}}$ and $\overrightarrow{MV_{23}}$ when $\overrightarrow{MV_{45}}$ is not received

$$\overrightarrow{MV_{34}} \leftarrow 2\overrightarrow{MV_{23}} - \overrightarrow{MV_{12}} \qquad (3)$$

Strategy 4: choosing $\overrightarrow{MV_{01}}$ and $\overrightarrow{MV_{23}}$ when $\overrightarrow{MV_{12}}$ and $\overrightarrow{MV_{45}}$ are not received

$$\overrightarrow{MV_{34}} \leftarrow 1/2\ (3\overrightarrow{MV_{23}} - \overrightarrow{MV_{01}}) \qquad (4)$$

Strategy 5: choosing $\overrightarrow{MV_{23}}$ or $\overrightarrow{MV_{45}}$ when only $\overrightarrow{MV_{23}}$ or $\overrightarrow{MV_{45}}$ is received

$$\overrightarrow{MV_{34}} \leftarrow \overrightarrow{MV_{23}} \ \text{ or } \ \overrightarrow{MV_{34}} \leftarrow \overrightarrow{MV_{45}} \qquad (5)$$

Strategy 6: choosing $\overrightarrow{MV_{01}}$ and $\overrightarrow{MV_{12}}$ when neither $\overrightarrow{MV_{23}}$ nor $\overrightarrow{MV_{45}}$ is received

$$\overrightarrow{MV_{34}} \leftarrow 3\overrightarrow{MV_{12}} - 2\overrightarrow{MV_{01}} \qquad (6)$$

Strategy 7: choosing the vector, which is closest to $\overrightarrow{MV_{34}}$ in the received ones, to replace $\overrightarrow{MV_{34}}$ directly in the other cases.

4 Experiments

4.1 Choosing Strategies Testing

Segments of Sequence Akiyo are randomly extracted to test the validity of choosing strategies, where the first frames are intra-encoded and the others are inter-encoded. Assuming the fifth frames are suffered, the discarded parts of the fifth frames are concealed by the above strategies, respectively.

Figure 4. shows the test results of one of video segment (Frame 0 ~ Frame 5), where some part of Frame 4 is lost. Comparing Figure 4. (c) ~ (h), the corresponding PSNRs are decreasing, which validate the priority of choosing candidate vectors is right. Note, the PSNR of (g) is lowest because in this given video segment, the eyes part in the first four frames is slow-motion while there is quick-break from Frame 4 to Frame 5. Only the future motion vector is considered in (g), so the effect of Strategy 5 is worse than the one of Strategy 6 against.

(a) Original frame

(b) No concealment PSNR=19.07dB

(c) Strategy 1 PSNR=32.51dB

(d) Strategy 2 PSNR=32.17dB

(e) Strategy 3 PSNR=31.26dB

(f) Strategy 4 PSNR=31.09dB

(g) Strategy 5 ($\overrightarrow{MV_{45}}$) PSNR=29.77dB

(h) Strategy 6 PSNR=31.05dB

Fig.4 Reconstructed frames by using different candidate vectors

The average PSRNs gained by testing a great deal sequence segments are shown in Table 1: 1) the proposed multiple prediction method is effective on error concealment; 2) different candidate vectors have different abilities to conceal. It must be pointed out that Strategy 3 just is the improvement to dual forward prediction and Strategy 5 is single prediction actually.

Choosing strategies	PSRN(dB)
No concealment	19.02
Strategy 1	33.56
Strategy 2	31.66
Strategy 3	31.10
Strategy 4	31.04
Strategy 5	29.31
Strategy 6	28.41

Table 1 PSNRs of reconstructed frames

4.2 Internet Testing

The MPEG-4 Verification Model (without B frames) is used for coding the standard raw video sequence Akiyo in QCIF format under the Gilbert channel model. In order to avoid error propagation into the subsequent frames, the packetization algorithm based on FlexMux layer is adopted according to Ref.[7]. The goal of the packetization is that the data of the same frame is put into a packet as possible, so dependency among the packets can be removed. In the experiment, each packet contains one P-frame.

Shown as Table 2, 1) there are the different PSNRs under the different packet loss rates; 2) the higher is the loss rate, the stronger should be the degradation of the PSNRs; 3) the quality of reconstructed video is still acceptable in the case of 2 or 3 packets lost continuously.

values of p and q	probabilities of n continuous lost packets			PSNR(dB)
	n=1	n=2	n=3	
p=0	0	0	0	37.59
p=0.05 q=0.85	0.050	0.008	0.001	35.45
p=0.67 q=0.07	0.070	0.023	0.008	31.51
p=0.10 q=0.70	0.100	0.030	0.009	29.52
p=0.50 q=0.20	0.200	0.100	0.050	24.99

Table 2 PSNRs under different loss rates

5 Conclusion

In this paper, the new concealment method for P-frame is described in enough view of the relativities in the motion vectors of the interframes, and the experimental results are satisfied. It is pointed out that this paper only analyses temporal concealment, and in fact the neighbor motion vectors around the discarded parts of the same frame also be used to conceal if the appropriate interleaving technique is introduced. This will be our research in the future.

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