논문 98-02-16

Unequal Error Protection and Error Concealment Schemes for the Transmission of H.263 Video over Mobile Channels

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Abstract

This paper presents unequal error protection and error concealment techniques for robust H.263 video transmission over mobile channels. The proposed error protection scheme has three major features. First, it has the capability of preventing the loss of synchronization information in H.263 video stream as much as possible that the H.263 decoder can resynchronize at the next decoding point, if errors are occurred. Secondly, it employs an unequal error protection scheme to support variable coding rates using rate compatible punctured convolutional (RCPC) codes, dividing the encoded stream into two classes. Finally, a macroblock-interleaving scheme is employed in order to minimize the corruption of consecutive macroblocks due to burst errors, which can make a proper condition for error concealment.

In addition, to minimize the spatial error propagations due to the variable length codes, a fast resynchronization scheme at the group of block layer is developed for recovering subsequent error-free macroblocks following the damaged macroblock. Futhermore, error concealment techniques based on both side match criterion and overlapped block motion compensation (OBMC) are employed at the source decoder so that it can not only recover the lost macroblock more accurately, but also reduce blocking artifacts.

Experimental results show that the proposed scheme can be an effective error protection scheme since proper video quality can be maintained under various channel bit error rates.

I. Introduction

In the past few years, there has been significant interest in multimedia data transmission for low bit rate communication. For example, a standard for multimedia terminals over general switched telephone network (GSTN) is specified in the ITU-T recommendation H.324 that supports real-time audio and video communications for videophone [1]. As the next step, ITU-T has started to specify a new standard for terminals over mobile channels [2]. In particular, the above recommendations include the H.263 [3] as a video codec for low bitrate communication. The robust transmission of H.263-based encoded stream over mobile channels, like many other video standards [4], [5], is a very important issue, since it shows high error sensitivity resulting in spatio-temporal error propagations. Consequently, additional schemes for protecting video information from channel noise are inevitably required.

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Most popular methods used for protecting information from channel errors are the forward error correction (FEC) and automatic repeat on request (ARQ)[6], [7]. With the overhead data of error control code, FEC is an effective solution to random isolated errors, but has limitations to correct burst errors. On the contrary, the ARQ method has been known to be more effective than FEC for burst errors, since the receiver requests the sender to retransmit only corrupted data. However, additional delay introduced by the retransmission of corrupted data is critical for real-time applications.

In this paper, a FEC-based unequal error protection scheme is proposed for the robust transmission of H.263 encoded video over mobile channels. In the proposed error protection scheme, unequal error protection is employed for the layers of the encoded video using rate compatible punctured convolutional (RCPC) codes. The synchronization information among the encoded video is very useful for the source decoder to find the next decoding position when it detects errors. It is shown that the proposed error protection method can effectively prevent the loss of synchronization information such as the PSC (picture start code) and GBSC (group of block start code) in the encoded video. Moreover, our scheme employing macroblock-interleaving can minimize the corruption of consecutive macroblocks caused by burst errors.

The residual errors, which are not completely corrected by the error protection scheme, cause severe degradation of the decoded video quality. For the corrupted macroblocks detected by the source decoder, a spatio-temporal error concealment based on the side match criterion and overlapped block motion compensation is proposed. Furthermore, a fast resynchronization scheme is developed so that the source decoder can recover the subsequent error-free macroblocks following some erroneous macroblocks.

The rest of the paper is organized as follows. Section 2 briefly describes the layer structure of the H.263 encoded stream and the proposed error protection schemes are presented in section 3. In section 4, a fast resynchronization method and spatio-temporal error concealment based on the OBMC are described. In section 5, we present simulation results for our proposed scheme and evaluate the performance. Finally, section 6 concludes this paper.

II. H.263 video stream and error propagations

The H.263 video standard was developed for videophone applications over low bitrates communications. Comparing to the early H.261, the H.263 standard provides more advanced prediction techniques and flexibilities for macroblock coding.

The bit stream syntax of H.263 is based on hierarchical multiplex. For QCIF resolution, each picture is composed of 9 group of blocks (GOB) and one GOB has 11 macroblocks (MB). Each macroblock consists of four blocks for luminance and two blocks for chrominance. The simplified syntax diagram for the H.263 video is shown Fig. 1.

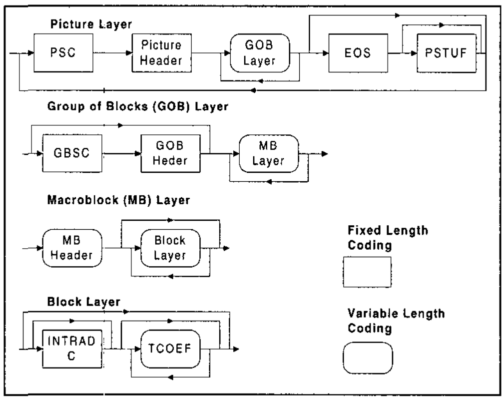

Fig. 1. Simplified syntax diagram for the H.263 video.

The corruption of the picture header is the most serious situation resulting in the loss of a whole picture.

Since variable length coding (VLC) is employed for the macroblock and block layers, a single bit error of these layers leads to the loss of synchronization so that all the subsequent blocks following the damaged block may be discarded. To minimize this spatial error propagation, the picture start code (PSC) in the picture header and GOB start code (GBSC) in the GOB header can optionally be inserted to provide the synchronization for the source decoder to find the beginning position of the next picture and GOB. Therefore, if the synchronization information is damaged, the error propagation is further progressed.

In the temporal domain, all the subsequent predictive pictures referenced from a damaged picture are naturally corrupted. In general, an intra-coded picture may be inserted into the predictive pictures to stop the temporal error propagation.

Based on the above observations, we divide the encoded stream into two classes. The first class with the most important data contains the picture header and synchronization information, and the second class is the rest. In the next section, we will present an unequal error protection scheme for these classes using RCPC codes.

III. Proposed error protection schemes

In this section, we propose a channel encoding scheme for H.263 encoded stream using the unequal error protection, and a macroblock-interleaving method.

A) Channel coding scheme

The synchronization information which is located at the front of each layer may be easily corrupted by channel noise since this information contains long consecutive zero bits. To avoid the loss of the synchronization information, we define new synchronization information, named picture header length (PHL) and GOB length (GL) indicating the length of the header of a picture and the length of each GOB. The modified bitstream for an encoded QCIF picture is shown in Fig. 2.

In the proposed channel encoder, class 0 including the PHL, the header of the picture layer, and GL's is highly protected using the convolutional code of rate 1/2 since this class is the most important information. On the contrary, the rest information (class 1) that is relatively less important than the class 0 is protected by RCPC codes of rate 2/3 or 3/4 [8].

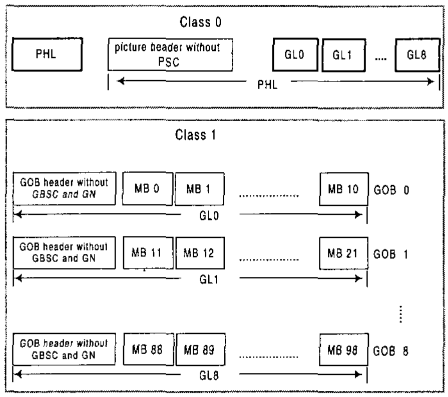

Fig. 2. Modified H.263 bitstream for the proposed channel coding.

The transmission procedure of the channel encoded stream and the decoding process are as follow: At first, the channel encoder sends the encoded PHL to the channel. Secondly, the picture header and GL's are transmitted. Finally, interleaved macroblocks are sent according to the predefined transmission order to be described in the next subsection.

The channel decoder decodes the fixed-length PHL at first and the picture header information using the decoded PHL. With the decoded GL's, the channel decoder can decide the length of GOB. After the channel decoding processing is completed for a picture, the decoder generates and inserts the PSC, GBSC's and GN's in the front of each layer. Using this scheme, we can efficiently prevent the loss of the synchronization information.

B) Macroblock-interleaving scheme

The corruption of consecutive macroblocks caused by burst errors can be prevented by a macroblock interleaving scheme. In the proposed scheme, one GOB is divided into some blocks and the divided blocks in even rows of GOB's are transmitted at first, and then blocks in odd rows are transmitted. Suppose that a picture has a 9 GOB's, and each GOB is divided into 2 blocks. The transmission order for macroblock-interleaving is shown in Fig. 3 where the numbers represent the transmission order of the corresponding block.

	block 0	block 1
GOB 0	0	5
GOB 1	10	14
GOB 2	1	6
GOB 3	11	15
GOB 4	2	7
GOB 5	12	16
GOB 6	3	8
GOB 7	13	17
GOB 8	4	9

Fig. 3. One example of transmission order for two divided blocks of GOB's.

With this scheme, the block length L_{ij} can be determined by

$$L_{ij}=\begin{cases} Integer(\ GL_i/N\ ) & \text{for } 0\le j<N-1 \\ Integer(\ GL_i/N\ )+Modulus(\ GL_i/N\ ) & \text{for } j=N-1 \end{cases} \quad (1)$$

where GL_i is the length of ith GOB and N is the number of divided blocks. Using the N, the channel decoder can decide the length of the current block to be received and decoded.

IV. A fast resynchronization scheme and error concealment

In this section, we propose a fast resynchronization scheme and error concealment techniques employed in the source decoder

A) A fast resynchronization scheme in a GOB layer

The loss of information at the GOB layer may be frequently occurred. Once one macroblock in the current GOB is corrupted, the subsequent macroblocks can not be correctly decoded due to variable length codes. Generally, as shown in Fig. 4, the decoding process resumes at the beginning of the next GOB using synchronization information (GBSC), even though all of macroblocks following the corrupted macroblock are error-free.

To overcome this problem, we propose a solution of recovering the subsequent error-free macroblocks instead of discarding them upto the next GBSC. This method is referred to as early resynchronization [9],[10].

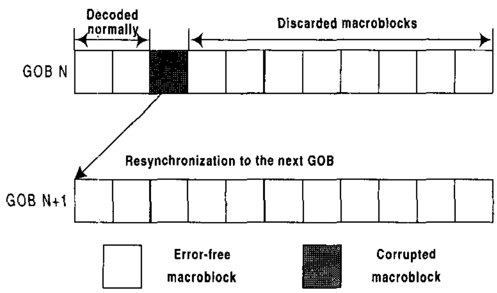

Fig. 4. General resynchronization when a macroblock is damaged.

The proposed early resynchronization is as follows. First, the decoder saves the first bit of the current decoding macroblock. If an invalid codeword is detected or the violation of syntax and semantics for H.263 is occurred, the decoder finds the last position of the

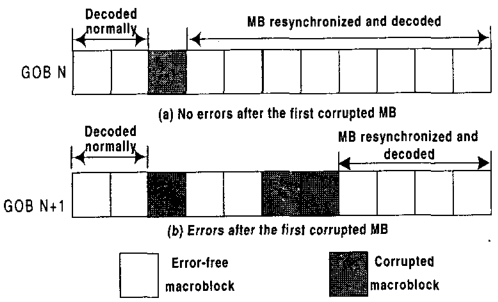

Fig. 5. Proposed fast resynchronization.

current GOB using the GBSC, and stores the last position. Next, it discards the first bit, and retries the decoding process with the next bit. This process is iterated until the decoding is correctly finished upto the last position of the current GOB. Finally, the decoder numbers the decoded macroblocks based on the last macroblock number of the current GOB for positioning the macroblocks exactly. We can avoid invalid recoverings by evaluating the spatio-temporal correlation between the recovered macroblock and its neighbours. Fig. 5 illustrates the proposed method of recovering consecutive error-free macroblocks upto the last macroblock in a GOB.

B) Error concealment techniques based on the OBMC

A lot of work has been accomplished on recovering the lost block using the side match criterion and its improvement techniques [11],[12]. Side match criterion finds the best match block with minimum gray-level transition across the block boundary as shown in Fig. 6 using the candidate motion vectors.

Next, we propose an effective error concealment technique for recovering lost macroblocks that can not be decoded by the early resynchronization method. The proposed method is based on side matching criterion using overlapped block motion compensated blocks to estimate the motion vector of the lost macroblock.

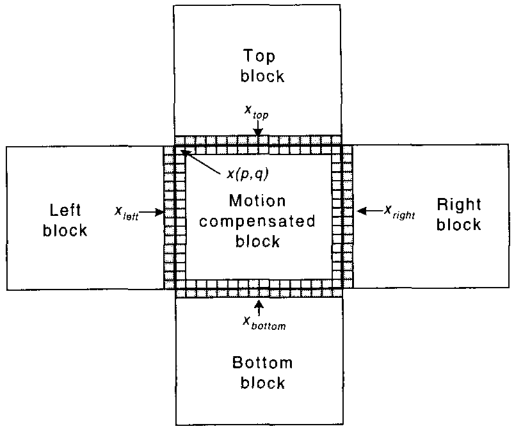

Fig. 6. The four boundaries used for side match criterion

Assume that $x(p,q)$ is a pixel value at the top-left corner of the lost block with a size of N x N. Then, four boundaries of neighbouring blocks denoted by x_{left}, x_{right}, x_{top} and x_{bottom} in Fig. 6 can be defined as follows.

$$\begin{aligned} x_{left} &= \{x(p-1, q+i) \mid i=0,1,\cdots,N-1\} \\ x_{right} &= \{x(p+N, q+i) \mid i=0,1,\cdots,N-1\} \\ x_{top} &= \{x(p+i, q-1) \mid i=0,1,\cdots,N-1\} \\ x_{bottom} &= \{x(p+i, q+N) \mid i=0,1,\cdots,N-1\} \end{aligned} \tag{2}$$

The expression for side match distortion is defined as

$$\begin{aligned} d_{Left} &= \sum_{i=0}^{N-1}[\hat{x}(p, q+i) - x(p-1, q+i)]^2 \\ d_{Right} &= \sum_{i=0}^{N-1}[\hat{x}(p+N-1, q+i) - x(p-1, q+i)]^2 \\ d_{Top} &= \sum_{i=0}^{N-1}[\hat{x}(p+i, q) - x(p-1, q+i)]^2 \\ d_{Bottom} &= \sum_{i=0}^{N-1}[\hat{x}(p+i, q+N-1) - x(p-1, q+i)]^2 \\ d_{sm} &= d_{Left} + d_{Right} + d_{Top} + d_{Bottom} \end{aligned} \tag{3}$$

where $\hat{x}$ is the pixel value of motion-compensated blocks using candidate motion vectors. Using the expression (3), we can choose the motion vector with minimum d_{sm} for the lost block.

In [12], a side match-based error concealment algorithm with overlapped block motion compensation is proposed to reduce blocking artifacts. In this algorithm, the lost motion vector among candidate motion vectors is first selected by the side match criterion and overlapped block motion compensation (OBMC) is then applied to four N/2×N/2 subblocks subdivided from the N×N motion compensated blocks in order to reduce blocking artifacts. The neighbouring blocks and weighting matrices used for overlapped motion compensation are shown in Fig. 7 and 8, respectively, when the block size is 16×16.

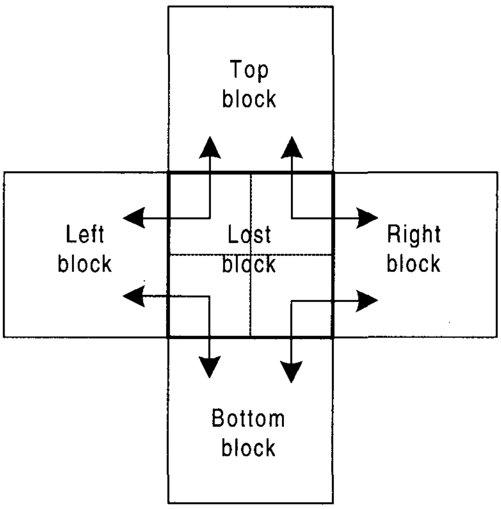

Fig. 7. The motion vectors used for overlapped motion compensation.

4	5	5	5	5	5	5	4
5	5	5	5	5	5	5	5
5	5	6	6	6	6	6	5
5	5	6	6	6	6	6	5
5	5	6	6	6	6	6	5
5	5	6	6	6	6	6	5
5	5	5	5	5	5	5	5
4	5	5	5	5	5	5	4

(a)

2	2	2	2	2	2	2	2
1	1	2	2	2	2	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	2	2	2	2	1	1
2	2	2	2	2	2	2	2

(b)

2	1	1	1	1	1	1	2
2	2	1	1	1	1	2	2
2	2	1	1	1	1	2	2
2	2	1	1	1	1	2	2
2	2	1	1	1	1	2	2
2	2	1	1	1	1	2	2
2	2	1	1	1	1	2	2
2	1	1	1	1	1	1	2

(c)

Fig. 8. Weighting values for overlapped block motion compensation.

(a) Weighting values, H_0, for current luminance blocks.

(b) Weighting values, H_1, for luminance blocks on top or bottom of current luminance block.

(c) Weighting values, H_2, for luminance blocks to the left or right of current luminance block.

In our scheme, on the contrary, overlapped block motion compensated blocks are recovered at first for the lost block, and then side matching is applied to estimate the lost vector. The pixel value $\hat{x}(p,q)$ of overlapped block motion compensated block is first computed by

$$\hat{x}(p,q) = (\hat{x_o}(p,q) \times H_0 + \hat{x_h}(p,q) \times H_1 + \hat{x_v}(p,q) \times H_2)/8 \tag{4}$$

where $\hat{x_o}(p,q)$, $\hat{x_h}(p,q)$, $\hat{x_v}(p,q)$ are motion compensated blocks using motion vectors of current, top or bottom, right or left block, respectively. Since spatial correlation between the overlapped motion compensated block and neighbouring blocks becomes significantly increased, this scheme can obtain more accurate motion vectors than side match criterion with ordinary motion compensated blocks. Particularly, to reduce computation for the OBMC, we compute only the boundary pixels of the block used for side match criterion.

It is very important to determine an effective search range for the side match criterion. In our scheme, the minimum and maximum values among motion vectors of macroblocks surrounding the lost macroblock are selected as a search range.

V. Simulation results

To evaluate the performance of the proposed method, simulation results are presented in this section. Four test sequences with different characteristics are employed for simulation. All sequences have 150 frames and the picture size is 176 x 144. All the PSC and GBSC are included in the encoded bitstream. Only the first frame is an I-picture and the rest frames are P-pictures to make a condition for the temporal error propagation. Simulation parameters are listed in Table I and the block diagram of the overall procedures for simulation is shown in Fig. 9.

TABLE I

Test sequences and simulation parameters.

Test sequences	Picture	Frames	Bit rates	Frame rates
Miss America	QCIF	150	16.50kbps	10fps
Mother and Daughter	QCIF	150	27.42kbps	10fps
Carphone	QCIF	150	35.01kbps	10fps
Foreman	QCIF	150	55.42kbps	10fps

We compared the performance of the proposed scheme to that of no error protection and a simple-temporal error concealment scheme. We use the following methods for comparison of their performances.

- Proposed error protection encoding the GOBs with RCPC codes of rate 2/3 (RCPC2).
- Proposed error protection encoding the GOBs with RCPC codes of rate 3/4 (RCPC1).

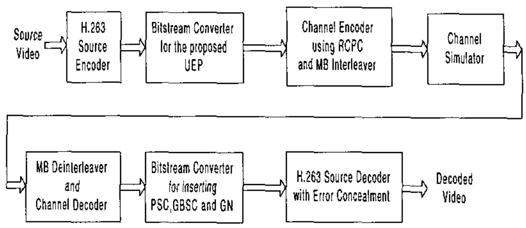

Fig. 9. The block diagram of the overall procedures for simulation.

- No protection of the video stream (NP).
- Proposed spatio-temporal error concealment and fast resynchronization (PEC).
- Simple-temporal error concealment that replaces the lost blocks with the corresponding block of the previous frame (S-TEC).

The average PSNR (peak signal to noise ratio) performance for each method is shown in TABLE Ⅱ. As can be seen in TABLE Ⅱ, the proposed error protection has 0.1～8.8dB gains in PSNR (peak signal to noise ratio) over the no error protection on the average for all the frames. In addition, the proposed error concealment including fast resynchronization yields 0.5～13dB higher on the average than the simple-temporal error concealment.

TABLE Ⅱ Comparison of average PSNR when BER is 5.24×10^{-4}.

Methods / Test sequences	No errors	NP + S-TEC	RCPC + SEC		RCPC + PEC	
			RCPC1	RCPC2	RCPC1	RCPC2
Miss America	37.08	23.49	26.29	32.39	32.71	32.84
Mother & Daughter	32.86	26.76	28.03	29.26	30.81	30.89
Carphone	33.26	15.35	16.36	15.76	24.94	29.00
Foreman	31.90	20.10	23.54	20.19	25.96	22.89

The PSNRs over all frames for Miss America, and Mother and Daughter are shown in Fig. 10 and 11, respectively.

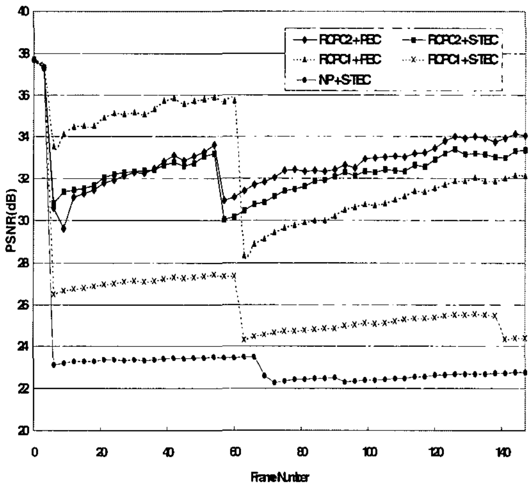

Fig. 10. Performance comparison in PSNR for Miss America (BER = 5.24 x 10^{-4}).

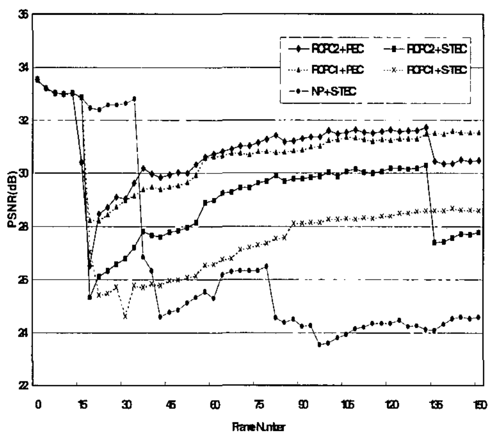

Fig. 11. Performance comparison in PSNR for Mother and Daughter (BER=5.24 x 10^{-4}).

VI. Conclusions

This paper proposes error protection scheme and error concealment techniques for the robust transmission of H.263 video over mobile channels. In the proposed error protection scheme, the encoded H.263 video stream is unequally protected by the RCPC codes for protecting the synchronization information. In addition, the scheme employs macroblock-interleaving mechanism to minimize the corruption of consecutive macroblocks due to burst errors, which can make a proper condition for error concealment. For the lost blocks that can not be corrected by the proposed error protection, error concealment and fast resynchronization schemes are employed in the source decoder.

In simulation, we compared our schemes with other techniques including no error protection and a simple error concealment. Simulation results show that the proposed error protection scheme produces good performance in PSNR for various video sequences. Moreover, fast resynchronization and error concealment based on side match criterion using overlapped block compensated blocks yields higher PSNR gains than the simple error concealment, especially for the fast motion pictures. Consequently, the proposed schemes can be one of effective methods for the robust transmission of H.263 video over noisy channels.

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