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Efficient redundant frames encoding algorithm for streaming video over error prone wireless channels

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Abstract: The H.264/AVC coding standard only specifies the decoding process and the bitstream syntax to allow considerable flexibility for the designers to optimize the encoder for coding performance improvement and complexity reduction. This paper proposes the use of redundant Predicted (Marionette) frames to prevent temporal error propagation in H.264/AVC streaming over error prone wireless channels. Compared with the H.264/AVC conventional redundant slices technique, our proposed approach can effectively enhance the smoothness of the video. A visual quality comparative study has been also carried out in order to validate the proposed approach.

Keywords: H.264/AVC, error concealment, redundant frame
Classification: Science and engineering for electronics

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1 Introduction

Video quality suffers significant degradation when transmitted over error-prone channels, due to packet loss, errors caused by fading in wireless channels and due to the video codec prediction mechanisms [1]. Adding redundant information to the compressed video, transmitted by the encoder, can significantly improve the error concealing abilities of the decoder. Redundant slices (RS) feature, is an error robustness feature allowing the encoder to send an extra representation of a picture region (typically at lower fidelity) that can be used if the primary representation is corrupted or lost. Redundant slices tool allow the insertion of primary slices and one or more additional secondary slices belongs to the original picture in the same bit stream. If a primary slice is affected by errors, it can be replaced by an error-free redundant one; otherwise the redundant slices are discarded. Moreover, messages to the decoder interleaved in the code stream containing supplemental enhancement information may contain further information about the bit stream, which can be utilized by an error concealment scheme. Coding of redundant slices may use different quantization parameters, different reference pictures, and different motion vectors than those used in the encoding of the primary slice. However, the parameters for encoding the redundant slices should be selected in such a way that there is no visual discrepancy between the primary and redundant slice representations [1, 2].

In the error concealment algorithms, to conceal the damaged macroblock, its neighboring macroblocks need to be correctly received. Thus, it is desirable to split the current macroblock and its neighboring macroblocks in a picture into different slices since one slice data typically fits one packet and bit errors usually make a whole packet useless, especially in today's wireless network. This can be fulfilled by a flexible slice organization format with the error resilience tool like flexible macroblock ordering (FMO) in H.264/AVC [2]. On the other hand, traffic congestion may still lead to burst consecutive packet losses and thus, it is possible that all or some of the macroblocks surrounding a damaged macroblock are also lost. This situation becomes even worse when the packet loss rate increases. In addition, in low bit rate packet-based video communication, the size for bitstream packetization of video pictures may be even smaller than the minimum transfer unit of the network used for video communication [3]. For example, when transmitting a low bit rate bitstream over a universal mobile telecommunications system (UMTS) link, a picture typically will be coded in one slice and fit in one packet. Therefore, a transmission error will lead to the whole picture loss. As a result, the error concealment approaches will no longer perform well in these situations [1, 3]. This Letter proposes a new redundant Predicted (Marionette)- {P(M)-} frames technique for H.264/AVC as described

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in the next section.

2 Proposed technique

The original H.264/AVC standard includes 3 profiles (baseline, main and extended), each having a different set of functionalities. The baseline profile is our main focus for this research, since it was designed primarily for low-cost applications which do not have a great amount of computational power. This profile is mainly used in mobile applications. For the baseline profile only I- and P- slices can be used and therefore only I- and P- macroblocks are supported [1]. We consider only I- and P- frames in a Group of Pictures (GOP). Assume that $N$is the distance between two successive I- frames, defining a GOP length.

In order to prevent temporal error propagation imposed by wireless video streaming, we propose the use of redundant Predicted (Marionette) {P(M)-} frames. The generation of the Predicted (P-) Marionette {P(M)-} coded frames can be described as follows

$$\begin{array}{ccccccc} I_{A0} \rightarrow & P_{A1} & \rightarrow & P_{A2} & \rightarrow \ldots\ldots\ldots \rightarrow & P_{A(N-1)} \\ & \downarrow & & \downarrow & & \downarrow \\ & P_{A1}(M) & & P_{A2}(M) & \ldots\ldots\ldots & P_{A(N-1)}(M) \end{array}$$

In the conventional coding the very first frame is Intra (I-) coded and each subsequent frame is inter-coded with the previous coded frame as its motion compensation reference. Note that arrows indicate motion compensation predictions relationships. P(M)- frame is not a real frame, instead is a predicted frame which repeats the previous frame, exploiting the motion compensation predictive coding technique between similar frames. The P(M)- frame encodes the difference between the same video frame and such a difference is almost zero. Actually the P(M)- frame contains codes for not coded Macroblocks (MBs) and are representing by fixed bit pattern [4]. Hence, it does not require a large number of bits to encode it. Effectively this results in repeating the previous frame in the decoder [5].

The H.264/AVC standard states that the conventional redundant slices (RS in the figure) representation should follow the corresponding primary frame as show in Fig. 1 (a). In order to highly protect the most important information in the frame, some specific slices are dedicated for Region of Interest (ROI) as a foreground, exploiting the foreground with left-over FMO type 2. Then, redundancy slices are generated representing the foreground ROI. Fig. 1 (a) shows a frame transmission when a foreground with left over FMO Type 2 is implemented together with the redundant slice feature. For simplicity, the ROI size was constantly set to 3 X 3 MBs in the middle of the frame [1].

In order to further enhance the H.264/AVC Redundant slices (RS) tool we have extended the tool to the Redundant P(M)- frame as depicted in Fig. 1 (b). Integrating the proposed redundant P(M)- frame allocation promises a powerful error resilient scheme. If a primary frame is affected

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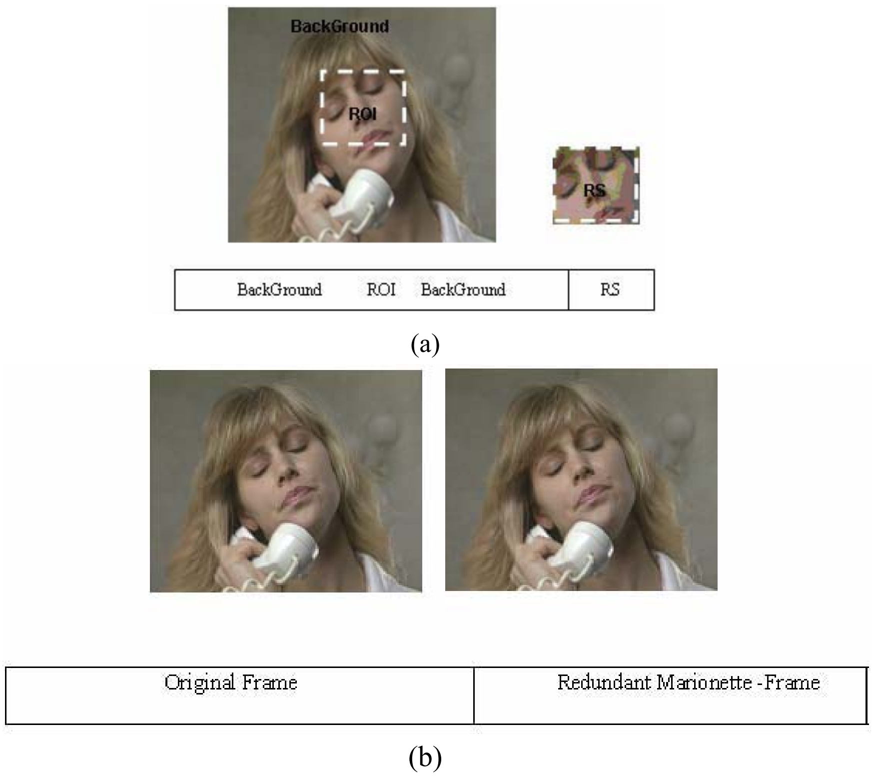

Fig. 1. Frame transmission with redundant feature. Standard redundant slices with FMO type 2 representation (a). Effective Redundant Marionette frames representation (b).

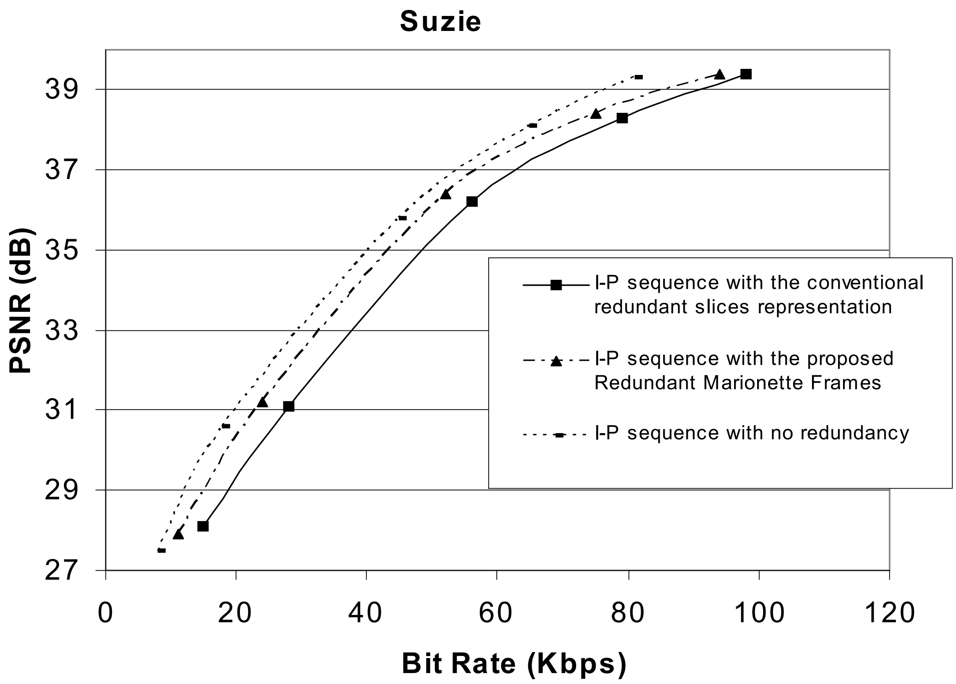

Fig. 2. PSNR as a function of Bit Rate for the QCIF Suzie video sequence.

by errors, it can be replaced by an error-free redundant marionette frame; otherwise the redundant marionette frame is discarded.

Fig. 2 illustrates a comparison of coding efficiency of I-P sequence with the

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conventional redundant slices representation, I-P sequence with the proposed redundant Predicted Marionette {P(M)} frames technique, I-P sequence with no redundant information to the compressed video, in terms of their PSNR as a function of bit rate.

It can be observed in Fig. 2, that the proposed technique has higher coding efficiency than the conventional redundant slices representation. As expected the redundant marionette frame technique has a minimum bit rate overhead compared to no redundancy approach. This is because the P(M)- frame encodes the difference between the same video frame and such a difference is almost zero.

3 Results

The proposed approach is evaluated and compared to H.264/AVC conventional scheme in terms of video quality and the ability to prevent temporal error propagation. Simulations were done using the H.264 Test Model [6]. We have used error concealment methods adopted by the H.264 standard, i.e., weighted averaging for INTRA frames, and boundary-matching-based motion vector recovery for INTER frames [1, 2]. The first frame in each group of pictures (GOP) is Intra (I-) encoded while the other consecutive frames are Inter encoded. In the testing, the bitstream is formatted as a series of NAL units (NALUs) and then packetized**.** The results reported here are for the Suzie sequence used in JVT contribution with QCIF resolution, encoded at 10 frames per second (fps). Similar results are observed for other sequences. Four packet loss patterns with average packet loss rates (PLRs) of 3%, 5%, 10%, and 20% used in ITU-T VCEG were employed [7]. We present the performance evaluation of the proposed redundant Predicted Marionette {P(M)} frames technique in comparison to all other cases. Specifically the three tested cases are indicated as follows: (a) "Normal" for no redundancy (b) "Conventional" for the conventional redundant slices representation when a foreground with left over FMO Type 2 is implemented together with the redundant slice feature and (c) "Redundant Marionette frames" for the proposed technique.

Fig. 3 shows the results achieved for each of the above cases for different packet loss rates in term of PSNR. From the same figure it can be noticed that he proposed Redundant Marionette Frames technique consistently achieves better results comparing all other cases for different packet loss rates. In the experiments, only the slice loss case is considered although the proposed technique can be simply extended to the whole- frame loss.

4 Conclusion

In this paper, we introduced a new redundant marionette frames technique for H.264/AVC. The proposed method greatly improves video transmission quality over lossy wireless channels. Simulations results indicate that the proposed method enhances the ability for error concealment, and therefore the video quality. Adding redundant Marionette frames to the compressed

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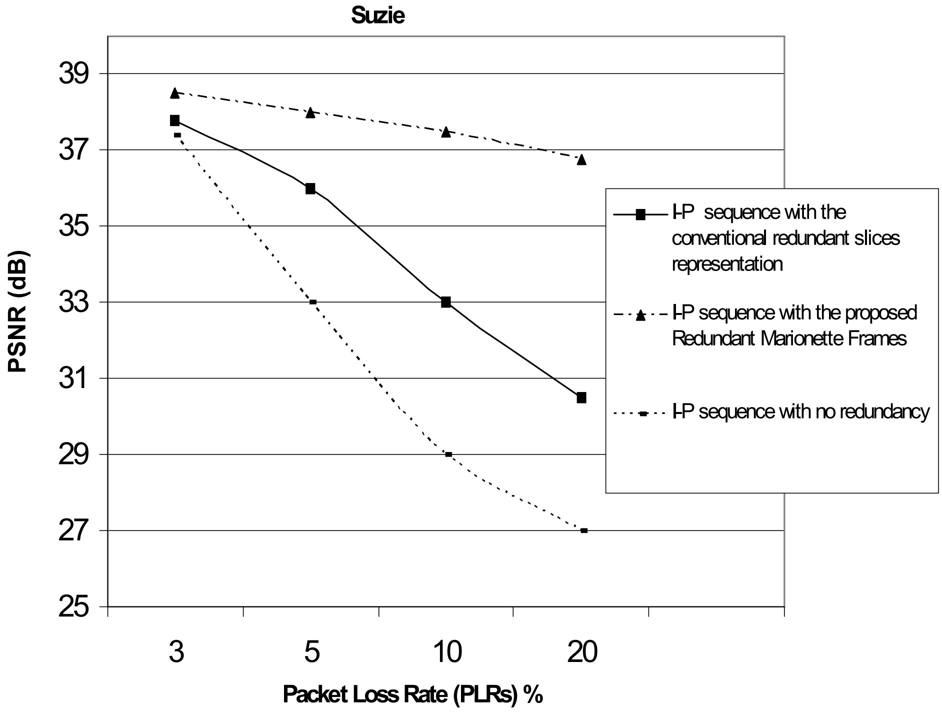

Fig. 3. Average PSNR as a function of different packet loss rates.

video sequence achieves better results compared to conventional redundant slices and no redundancy approaches for different packet loss rates. The only noticeable drawback of the proposed technique is a minimum of bit rate overhead compared to the no redundancy approach. The new concept of using redundant Marionette frames for H.264/AVC, presented here, can be an impetus for novel research directions in the area of resilient video transmission over wireless networks. Future work involves optimization of the proposed Redundant Marionette Frames technique utilizing statistical wireless/wireline channel characteristics.

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