# Error Concealment Using a Digital Watermarking Technique for Interframe Video Coding

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**Abstract**: A new approach of error concealment using a digital watermarking technique for interframe video coding is presented in this paper. In the proposed method, the most important feature of the reference frame is extracted. Then, this feature is embedded into the prediction error of current frame prior to transmission. Error concealment is achieved by means of recovering the erroneous reference frame using the embedded data before the reconstruction of current frame is performed. Simulation results demonstrated the effectiveness of the proposed method.

## 1. Introduction

To alleviate serious image degradation due to channel error in video decoding, various error concealment techniques have been proposed [1], [2], [3], [4], [5] and those that employ motion vectors (MVs) have been widely used.

However, most of the existing motion vectors based error concealment schemes not only need very computationally intensive work but also possess a very high dependency on the presence and quality of the reference picture. If the reference picture cannot be decoded due to data loss, the decoder will not be able to reconstruct the whole frames in a video sequence. Accordingly, it is very important to secure the reference picture against the error impact during transmission process.

With these underlying concerns in mind, we proposed a new method of error concealment for interframe video coding. Our novel approach is implemented by adopting a digital watermarking technique [6], [7], [8], where the most important feature of the reference frame is extracted and then embedded into the prediction error of the current frame.

Identification of the most and the least important feature of an image can be simply done by adopting layer based coding tools, such as JPEG2000 and MPEG-4 [9]. In those coding tools, the most important bits that pertain to most significant contribution to the image quality are placed in the first layer while the least important bits are placed in the last layer of the bit stream.

In this paper, we utilized the JPEG2000 codec [10] which is extended for interframe video coding to demonstrate the proposed method. From now on, we use the "most significant layer (MSL)" term to refer to the most important feature and the "least significant layer (LSL)" term to refer to the least important feature contained in an image.

## 2. Interframe Video Coding and Its Problems

### 2.1 Review of Interframe Video Coding

In video coding, data compression is achieved by reducing the spatial and temporal redundancies in every frame. One efficient way to minimize the temporal redundancy is to apply motion compensation between frames. This is commonly referred as interframe coding.

A general interframe video codec works as shown in Figure 1. The reference picture (Frame A) is initially encoded and sent to the decoder. This picture is also locally stored at the encoder so that it can be compared with the next picture (Frame B) to find MVs. Using the reference picture and these vectors, the predicted current frame (Predicted Frame B) is constructed. Subsequently, this predicted frame is compared with the actual picture (Frame B) to produce the prediction error or also called as the residual image. Then the prediction error is transmitted along with the MVs. At decoder, the reference picture (Received Frame A) is also held in memory. The received MVs is then employed to the stored reference picture to regenerate the predicted current picture (Predicted Frame B*). Eventually, the prediction error is added to the predicted frame in order to reconstruct the current picture (Decoded Frame B).

The above mentioned steps are applied to the next frames in one group of pictures (GOP).

### 2.2 Problems of Interframe Video Coding

When compressing a video sequence using the interframe coding scheme, we will be encountered by two categories of errors at the decoder side:

- **Bitstream errors**

They are resulted by direct signal loss of some or the whole compressed bitstream of a coded image or a prediction error.

- **Propagation errors**

They are uniquely originated in the predicted frames by the additional use of motion compensated time information for their reconstruction. Errors in the formerly decoded reference frames propagate to the adjacent frames in the decoding order.

These two kinds of errors may badly damaged the video image if appropriate error concealment technique is not employed at the decoder. In the worst case, when the reference frame is undecodable, the decoder will not be able to reconstruct the whole frames in one GOP.

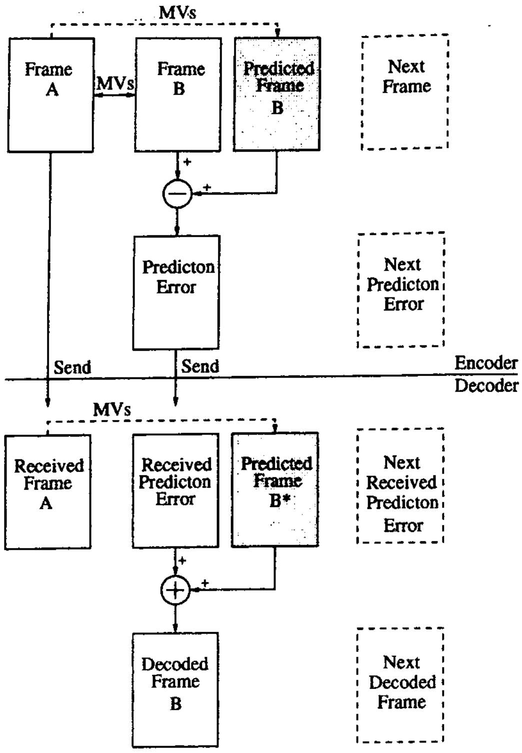


Figure 1. General Interframe Video Codec.

Thus, no information is viewable during the corresponding time.

## 3. Proposed Method

As already stated in the previous section, our method utilizes the availability of coding tools that can encode an image into a scalable bit stream, in this case we employed JPEG2000 codec.

A JPEG2000 bit stream packs the image data in a layered fashion. The most important bits that pertain most significant contribution to the image quality are placed in the first layer (MSL). While the least important bits are placed in the last layer(LSL). Therefore, the JPEG2000 bit stream enables us to identify the most and the least important feature of an image easily.

In the proposed method, the MSL of the reference frame is extracted. Then, this feature is embedded into the LSL of prediction error of current frame prior to transmission. Error concealment is achieved by means of recovering the erroneous reference frame using the embedded data before the reconstruction of current frame is performed.

Though we adopted the general interframe video coding as outlined in section 2, there are several additional steps that included in the proposed method. These steps will be discussed further in following parts. For simplicity, we define a GOP consits of I-P-P-P-P frames.

### 3.1 Procedures at Encoder

Figure 2 illustrates the extracting and embedding process that done in the encoder side. The rectangles represent the bit streams of each reference frame and

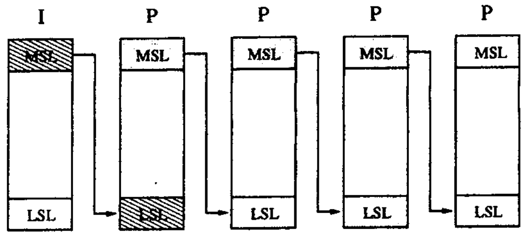


Figure 2. Extracting and Embedding Process at Encoder Side.

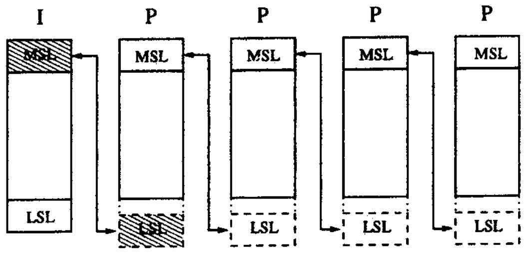


Figure 3. Extracting and Comparing the MSL at Decoder Side.

prediction errors correspondingly.

The following procedures are performed at the encoder.

1. The reference frame is intra-coded then send to the decoder.
2. By using the reference picture and its next frame, the predicted picture of the current frame is generated.
3. Then the prediction error is obtained by subtracting the current frame to the predicted picture.
4. The MSL of the reference frame is then extracted and embedded into the LSL of the prediction error bit stream.
5. The embedded prediction error is then sent to the decoder.
6. Steps 2-5 are employed to all consecutive frames.

### 3.2 Procedures at Decoder

At the decoder side, after receiving the encoded reference frame and embedded prediction error, the following procedures are carried out.

1. Extract the embedded MSL from the LSL of prediction error bit stream then this LSL is truncated.
2. Compare the extracted MSL with the one in the encoded reference frame for concealment purposes. When the MSL of the reference frame is affected by errors, the loss data is recovered by the extracted MSL from the encoded prediction error. We depicted the process in steps 1-2 in Figure 3. The truncated LSL is represented by the dotted lines.
3. Decode the concealed reference frame.
4. Using the decoded reference frame, the predicted frame is regenerated.
5. By adding the decoded prediction error to the regenerated predicted frame, the current frame is reconstructed.

6. Steps 1-5 are employed to all consecutive encoded prediction errors.

# 4. Simulations

To verify the effectiveness of the proposed method, we demonstrated some simulations. The method was employed to a standard video sequence named "mobile and calendar" (grayscale, $720\times576$ pixels) with the GOP of I-P-P-P-P. The target bit rate for all frames was 1.0 bits/pixel (bpp) and all bit streams were formed into 20 layers.

Simulations were carried out under three circumstances that possibly generated by transmission channel: without errors, in the presence of errors and in the entire loss of reference picture. We considered only random error with bit error rate (BER) $10^{-3}$ and $10^{-4}$ for representing error channel.

Performance of the proposed method was measured in terms of peak signal-to-noise-ratio (PSNR) between the original frames at the encoder and the corresponding reconstructed frames at the decoder. Higher PSNR means better performance.

## 4.1 Simulation without Errors

In this part, we simulated the interframe and intraframe video coding in the absence of error and also we verify the effect of data embedding in interframe coding.

As shown in Figure 4, we confirmed that the interframe coding outperformed the intraframe coding. Then, the performance of the codec that applied the proposed method is only a slight difference from the one achieved by the general codec. This means that the image degradation caused by data embedding is negligible.

## 4.2 Simulation with Errors

Figure 5 and Figure 6 describe the simulation results considering a random error channel with BER $= 10^{-3}$ and BER $= 10^{-4}$. It is obvious that the proposed error concealment technique worked quite well. Figure 7 and Figure 8 show the reconstructed frame 1 considering erroneous channel (BER $= 10^{-3}$) without and with concealment.

## 4.3 Simulation with Loss of Reference Picture

In this part, we assumed the bit stream of reference picture (frame 0) was undecodable due to severe transmission error. Hence, the decoder experienced total loss of reference frame. Figure 9 shows the result of this simulation. As can be seen, a general decoder is unable to generate any viewable pictures when encountered with this problem, reflected by a very low PSNR (around 13.6 dB).

Figure 10 and Figure 11 illustrate the decoded frame 1 resulted by the general decoder and the proposed decoder in the loss of frame 0 respectively.

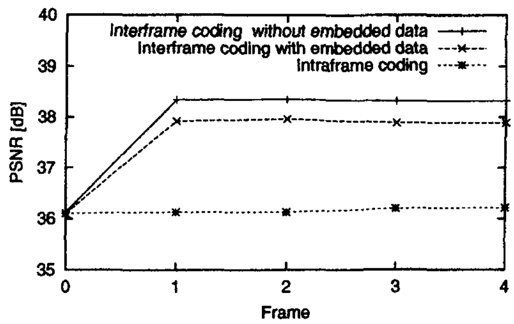


Figure 4. Effect of Data Embedding in Interframe Coding and Performance Comparison of Interframe and Intraframe Coding.

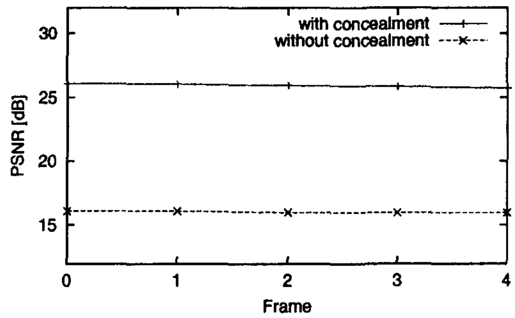


Figure 5. Quality of Error Concealment (BER $= 10^{-3}$).

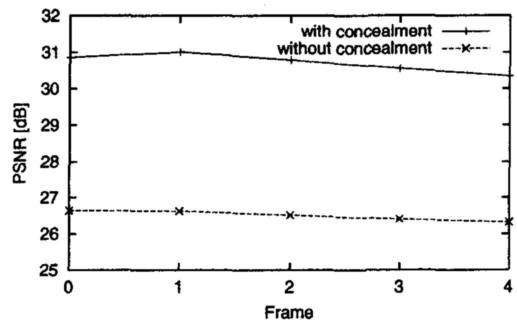


Figure 6. Quality of Error Concealment (BER $= 10^{-4}$).

# 5. Conclusions

We proposed a new approach of error concealment for interframe video coding. Different from the existing method, our scheme is based on a digital watermarking technique which extracts the most significant layer of a video frame bit stream and embeds it into the next prediction error bit stream prior to transmission. Simulation results demonstrated the effectiveness of the proposed method.

## References


[1] P. Salama, N. B.Shroff and E. J. Delp, "Error concealment in MPEG video streams over ATM networks," *IEEE Journal of Selected Areas in Communications*, Vol.18, No.6, pp.1129-1144, June 2000.

[2] A. K. Katsaggelos, F. Ishitiaq, L. P. Kondi, M. -C.

Figure 7. Decoded Frame 1 without Concealment (BER=$10^{-3}$, PSNR = 16.105 dB).

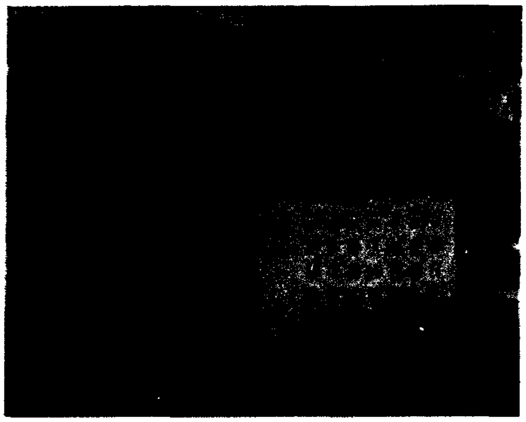

Figure 8. Decoded Frame 1 with Concealment (BER=$10^{-3}$, PSNR = 26.100 dB).


Figure 9. Performance Comparison of General and Proposed Decoder (without Frame 0).

Figure 10. Frame 1 Decoded by General Decoder (Without Frame 0, PSNR = 13.603 dB).

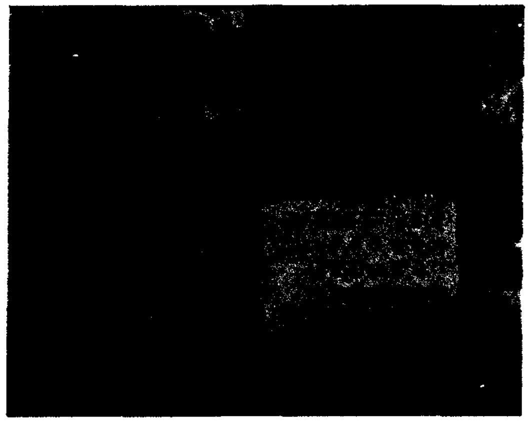

Figure 11. Frame 1 Decoded by Proposed Decoder (Without Frame 0, PSNR = 24.898 dB).


Hong, M. Baham, and J. Braiean, "Error resilience and concealment in video coding," *Proc. IX European Signal Processing Conference*, Rhodes, Greece, pp.221-228, Sept. 1998.

[3] H. Song, T. Song, H. Okada, G. Fujita, T. Onoye, and I. Shirikawa, "An error concealment algorithm using motion estimation method for MPEG-4 video,*IEICE Technical Report*, DSP2000-107, Oct. 2000.

[4] Y. Wang, Q. Zhu, "Error control and concealment for video communication: A Review,"*Proc. IEEE*, Vol.86, pp.974-997, May 1998.

[5] M. Kurosaki, H. Kiya, "Error concealment using a data hiding technique for MPEG video,"*IEICE Trans. Fundamentals*, Vol.E85, No.4, April 2002.

[6] H. Kiya, Y. Noguchi, A. Takagi, and H. Kobayashi, "A method of inserting binary data into MPEG video in the compressed domain,"*IEICE Trans. Fundamentals*, Vol.E82-A, No.8,pp.1485-1492, Aug. 1999.

[7] Y. Noguchi, H. Kobayashi, and H. Kiya, "A method of extracting embedded binary data from JPEG bitstreams using standard JPEG decoder," *IEICE Trans. Fundamentals*, Vol.E-83A, No.8, pp.1582-1588, Aug. 2000.

[8] K. Ando, H. Kobayashi, and H. Kiya, "The method for embedding binary data into JPEG2000 bitstreams based on the layer structure," *IEICE Technical Report*, IE2000-152, pp.67-71, Jan. 2001.

[9] I. Moccagata, S. Sodagar, J. Liang and H. Chen, "Error-resilient coding in JPEG-2000 and MPEG-4,"*IEEE Journal of Selected Areas in Communications*, Vol.18, N0.6, pp.899-914, June 2000.

[10] JPEG2000 Verification Model 8.6 Software, *ISO/IEC JTCI/SC29/WG1 WG1 N1894*.