Error Concealment using a Data Hiding Technique for MPEG Video

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Abstract — **A new method of error concealment for MPEG videos is proposed in this paper. In this method, motion vectors are hidden into an MPEG bitstream as watermark. Several conventional methods conceal error regions by using motion vectors, which are re-estimated in a decoding process. These methods, however, have two problems; (1) The accuracy of a re-estimated motion vector is lower than that of an estimated motion vector in an encoding process. (2) A large amount of calculation is required to re-estimate motion vectors. The proposed method overcomes these problems by using hidden accurate motion vectors. This method hides several bits into each 8×8 DCT block of all frames and, simultaneously, inhibits the image degradation caused by hiding motion vectors. In addition, the proposed method has the upward compatibility with a standard MPEG decoder and allows conventional methods to combine with. Simulation results show that the accuracy of error concealment is higher than that of the conventional method.**

1 Introduction

Recently, the importance of the video communication through mobile telecommunication networks has been increased. Since those networks have the relatively high bit error rate, some regions of the video data transmitted through wireless networks may not be decoded. Therefore, the quality of decoded video images is degraded.

In such a situation, MPEG-4 (Moving Picture Experts Group)[1], an international standard for video compression, allows error concealment in a decoding process. There are two types of the conventional methods for error concealment[2, 3], methods not using motion vectors and ones using them. It is known that the latter are superior to the former in concealing error regions. The latter, however, require to re-estimate motion vectors, which causes a large amount of calculation. In addition, the accuracy of re-estimated motion vectors in a decoding process is lower than that of estimated motion vectors in an encoding process.

In this paper, a novel method for error concealment that hides motion vectors into an MPEG bitstream is proposed. The motion vectors estimated in an encoding process are hidden into each video frame and are used for error concealment in the proposed method. Consequently, the accurate motion vectors are obtained in a decoding process without re-estimation even the error rate is high. Furthermore, the proposed method has the upward compatibility with a standard MPEG video decoder and, simultaneously, allows the conventional error concealment methods to combine with. Therefore, the lower bound of the quality of the error concealment is equal to that of conventional methods. As the data hiding technique, an extended version of the methods that were previously proposed by the authors[4, 5] is employed. While several bits are hidden into each 8×8 DCT block, the image deterioration is inhibited by the employed technique.

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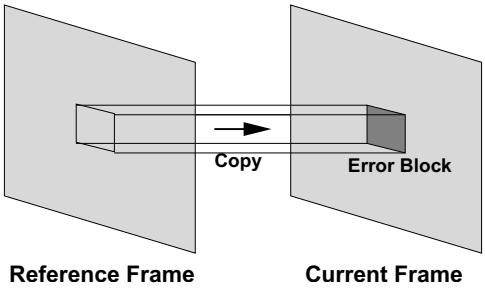

Figure 1: Block copy without motion vector.

2 Conventional Methods for Error Concealment [2, 3]

Conventional error concealment methods and their problems are summarized in this section.

2.1 Methods without Motion Vectors

There are two types of methods for error concealment without motion vectors; methods that copy the corresponding blocks from the reference frame and ones interpolate between the circumferential pixels of the error regions in the current frame.

Figure 1 shows an example of the former, where the dark region in the current frame represents an error block missing information completely. In these methods, a block in the reference frame is copied onto the same position as the error block in the current frame. The amount of calculation in these methods is small, because there is no need to re-estimate motion vectors. The quality of error concealment is degraded when the error part has a movement in these methods.

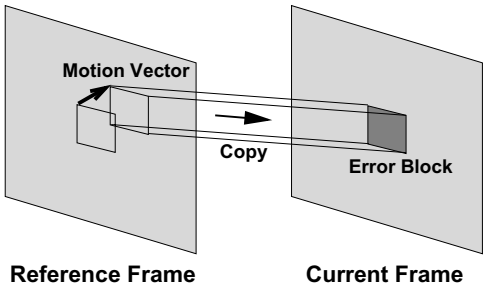

Figure 2: Block copy with motion vector.

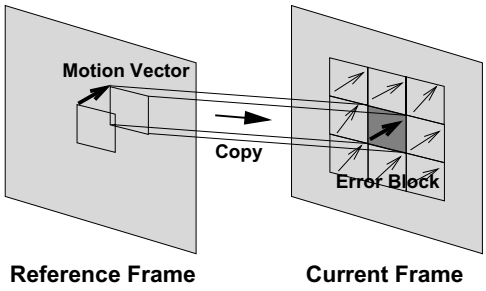

Figure 3: Motion estimation using motion vectors in circumferential blocks of error block.

On the other hand, the latter, interpolation methods, interpolates between decoded pixels around the error regions. If there is an edge of an object in the error regions, the quality of the concealed image is degraded.

2.2 Methods with Motion Vectors

An example of a method using motion vectors is displayed in Fig. 2. In this figure, the dark region in the current frame represents an error block, and the arrow in the reference frame is a re-estimated motion vector. In this method, a block pointed by the re-estimated vector in the reference frame is copied onto the error block in the current frame. Since the quality of error concealment depends on the accuracy of re-estimated motion vectors, this method requires on algorithm that re-estimates motion vectors with good accuracy.

There are two algorithms for re-estimating motion vectors in this scheme. One estimates a new vector from motion vectors of circumferential blocks of the error block. The other estimates a new vector by using the accurate pixels of the circumferential blocks.

Figure 3 depicts an example of the former. Thin arrows represent motion vectors in circumferential blocks of an error block. The fat arrow is the motion vector that is re-estimated by using vectors of circumferential blocks. When the direction of the movement differs between the error block and the circumferential blocks, the quality of error concealment is degraded.

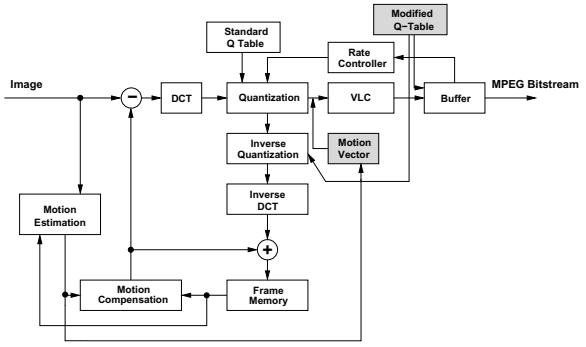

Figure 4: Block diagram of an extended MPEG encoder which hides motion vectors.

In the latter algorithms, the motion vector in the error block is estimated by using the surrounding pixels of the error block in the current frame. Since this algorithm estimates new motion vectors from pixel values, it requires a huge amount of calculation.

3 Proposed Method

The error concealment method for MPEG video that employs a data hiding technique is proposed in this section. First, the amount of hidden data that is required to conceal an error block is estimated. Next, the methods of hiding data and concealing errors are described.

3.1 Amount of hidden data

An accurate motion vector is hidden into each 16×16 macro block in an encoding process to improve the quality of error concealment. One motion vector and one identifier classifying frames, which are I (Intra coded), P (Predictive coded), and B (Bidirectionally predictive coded) frame, are required for each macro block.

For example, if a search-window size is set to ± 15, the required data consists of two bits for the identifier and 10 bits for a motion vector. Thus, data of 12 bits is required for each macro block and three bits are hidden into each 8×8 DCT block.

3.2 Methods of Hiding Data and Concealing Error

Figure 4 depicts a block diagram of the extended MPEG encoder that hides motion vectors into a video bitstream. In this figure, the colored squares represent the differences from a standard MPEG encoder. Figure 5 describes a block diagram of the MPEG decoder which can extract hidden motion vectors. In this figure, a dotted-line arrow represents the flow of hidden motion vectors, which a standard MPEG decoder does not use nor require.

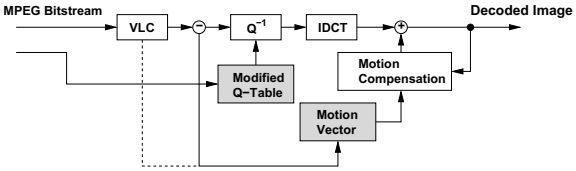

Figure 5: Block diagram of an MPEG decoder which can extract hidden motion vector.

Methods of hiding data into JPEG and MPEG images have already been proposed[4, 5]. However, in these methods, only one-bit data is hidden into each 8×8 DCT block and data is not hidden into P nor B frames. Since it is considered that a large amount of data is hidden mentioned in section 3.1, data of several bits is hidden into each block in all frames in this proposed method.

The followings are required to a technique hiding motion vectors into images: (a)Precious extraction of the hidden binary data (b)Inhibit of image deterioration.

To extract the hidden data precisely, the data is hidden into quantized DCT-coefficients. Three coefficients are chosen from 64 coefficients in a DCT block to hide three bits, and the magnitude of a chosen coefficient is replaced by '0' or '1.' The chosen coefficients are $AC(61) \sim AC(63)$, where $AC(p)$ represents the p-th quantized DCT coefficient of the zigzag scanned sequence. Thus, this proposed method hides data into the highest frequencies of each DCT block. To inhibit the image deterioration caused by hiding the data, a modified quantization table is employed in a decoding process. The values of quantization table corresponding to chosen coefficients are replaced by '1.'

In the concealment process, the error regions are concealed by using the hidden motion vectors. Blocks corresponding to hidden motion vectors in the reference frame are copied onto the error blocks. Consequently, re-estimation of the motion vectors is not required. Since this proposed method exploits the accurate motion vectors, the quality of error concealment is improved. Furthermore, the proposed method can be combined with the conventional methods. Thus, the lower bound of the error concealment accuracy of the proposed method is equal to that of conventional methods.

The proposed method has a large degree of freedom to select a macro block into which a motion vector is hidden. It is considered that data is hidden into the corresponding place in the reference frame or other blocks in the current frame. It is considered that the location of the block where the data is hidden is decided according to the robustness against errors and the ease of the process.

4 Performance Evaluation

Performance of the proposed method is investigated by simulations under the conditions described in section 4.1. First, the image deterioration caused by hiding motion vectors is evaluated in section 4.2. Then, the quality of the error concealment is examined in section 4.3.

4.1 Conditions

Two grayscale video sequences, "Flower Garden" and "Football," are employed for evaluation. Each sequence consists of 16 frames and each frame consists of 704×240 pixels. These sequences are encoded by the MPEG-1 algorithm within the MPEG-2 software encoder[6] and the bitrate is set to 1 [Mbps]. As the encoding parameters, it is assumed that the GOP consists of nine frames and the distance between I frame and P frame is three. Performances are evaluated in the quality of images by the PSNR (Peak Signal-to-Noise Ratio) defined as

$$PSNR = 10log_{10}\frac{ImageSize \times 255^2}{\sum_{i=1}^{rows}\sum_{j=1}^{cols}\{p(i,j)-f(i,j)\}^2} \quad [dB],$$

where $p(i,j)$ and $f(i,j)$ represent a luminance of the pixel before the compression and that of the decoded, respectively. Since there is a close relationship between two sequences, results for "Football" are left out from this paper for its simplicity.

4.2 Image Deterioration by Hiding Motion Vectors

In this section, the image quality caused by hiding motion vectors is evaluated using a standard MPEG decoder. Since the data of three bits is hidden into each DCT block described previously, 7920 bits (990 bytes) are hidden into one frame in this evaluation. Instead of its original specification[4, 7], the conventional scheme hides three bits into each 8×8 DCT block by replacing the LSBs of three low frequencies. In addition, the conventional method hides data into all frames instead of I frames used in the original[4, 7]. Figure 6 shows the image deterioration.

From Fig. 6, it is found that the proposed method almost achieves the same quality as the standard MPEG video. The PSNR of the proposed method is 0.6 [dB] lower than that of the standard MPEG video at the worst frame. While, the conventional method deteriorates the decoded images $1\sim2$ [dB] lower in the PSNR than the proposed method. On the other hand, Fig. 6 describes that employing the modified quantization table inhibits the image deterioration as $2\sim8$ [dB] in the PSNR.

As these results, it is found that the image degradation caused by hiding motion vectors in the proposed method is almost nothing. In addition, it is found that

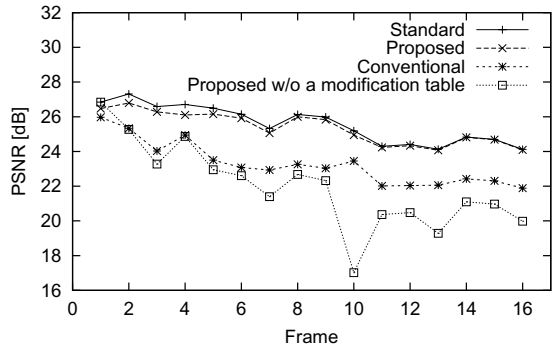

Figure 6: Image deterioration by hiding motion vectors.

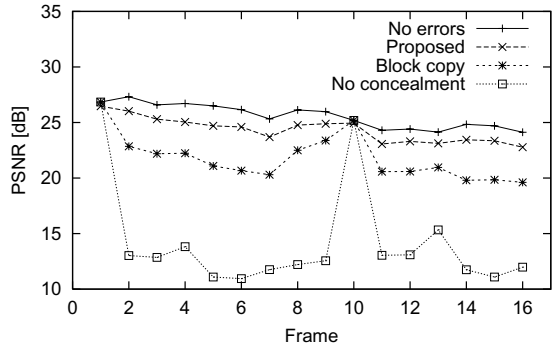

Figure 7: Quality of error concealment.

the modified quantization table contributes an inhabitation of the image deterioration efficiently.

4.3 Quality of Error Concealment

The quality of error concealment is discussed in this section. It is assumed that an error block is generated randomly and independently in the rate of 10^{-1}. It is noted that errors occur on P and B frames in this simulation. The proposed method is compared with the block copy method described in section 2.1. Figure 7 represents the quality of the error concealed-image.

From Fig. 7, it is found that there is still a room for improvement, though the conventional method improves the quality of images in comparison with no concealing. The proposed method further improves the quality of images 2$\sim$4 [dB] in comparison with the conventional method and makes the performance close to the limit.

5 Conclusions

A novel method of error concealment for MPEG video using a data hiding technique has been proposed in this paper. In this proposed method, accurate motion vectors are hidden into video frames in an encoding process and errors are concealed using those hidden motion vectors in a decoding process. Therefore, the proposed method retrieves accurate motion vectors without re-estimating vectors that requires a large amount of calculation. In addition, the proposed method has the upward compatibility with a standard MPEG decoder and allows conventional error concealment methods to combine with.

Simulation results have shown that the image deterioration by hiding motion vectors is almost nothing, in spite of about 1000 bytes hiding into a frame. Furthermore, it has been found that the proposed method is superior to the conventional method in error concealment.

This proposed method is evaluated in video transfers over telecommunication networks, as a future work.

Acknowledgement

This work has been supported in part by Grant-in-Aid for Scientific Research No.11875088 from the Japan Society for the Promotion of Science.

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