# AN EFFICIENT ERROR CONCEALMENT METHOD FOR JPEG2000 IMAGE TRANSMISSION

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# ABSTRACT

This paper presents two error concealment (EC) techniques for image transmission in JPEG2000, one for the lowest frequency coefficients (the low-frequency EC) and the other for high frequency coefficients (the high-frequency EC). The low-frequency EC algorithm uses a data hiding technique and the packet structure of JPEG2000. The low-frequency coefficients, which are taken as the hidden data, are extracted from the compressed bitstream, and embedded back into the same bitstream. The restored hidden data is used to conceal errors. The high-frequency reconstruction is performed on a bitplane basis. The damaged bitplanes are recovered according to the correlation in the wavelet subbands structure, in which the edge information is detected at first. Experiments show the effectiveness of these algorithms.

#### **1. INTRODUCTION**

The compressed video/image bitstream is sensitive to errors caused by channel noise during transmission. So, error resilience issue has become a necessity. Error concealment (EC) is an effective error resilience method that intends to conceal the effects of residual errors staying in the bitstream after transmission.

The new standard JPEG2000 contains some error resilience tools such as entropy coding and packet levels. These tools are used to detect and locate the errors, and also to resynchronize the decoding process. They can minimize the effect of errors in images, but are only applied at the source coding stage. The errors during transmission will still cause the loss of some wavelet coefficients [1]. JPEG2000 does not standardize any EC method. Only JPEG2000 VM 7.2 proposes to replace the lost wavelet coefficients by zeros, which will affect the image quality in a certain extent. So, more efficient EC techniques for JPEG2000 are necessary.

Some well-known EC techniques are reviewed in Paper [2]. Some of the proposed error concealment methods for JPEG2000 actually aimed at the study of wavelet-based coding [3] [4] [5]. These methods did not take full advantage of the JPEG2000 code stream itself. In a recent work [6], the authors proposed to use the data hiding to facilitate EC, which employed the layer structure of a JPEG2000 bitstream. But the method required that the length of the least significant layer must be the same as that of the most significant layer. Paper [7] presented a novel error concealment algorithm on JPEG2000 bitplane basis that recovered the damaged bitplanes according to the correlative information. But the method couldn't be used to recover the lowest frequency level.

In this paper, an efficient EC method to recover the damaged wavelet coefficients for JPEG2000 is proposed which improves on the above methods and takes the advantage of the code stream itself. The method consists of two parts. The low-frequency EC algorithm uses the data hiding technique. The packets containing the lowest frequency coefficients are extracted from the compressed bitstream, and embedded back into the same bitstream. The embedded data is used to conceal errors. The high-frequency recovery is performed on a bitplane basis. The damaged bitplanes are recovered according to the correlation in the wavelet subbands structure. The edge information is detected at first.

This paper is organized as follows. Section 2 briefly reviews the features of the JPEG2000 code stream and the general concept of exploiting the data hiding to facilitate error concealment. Section 3 describes the framework and the details of the proposed scheme. Experimental results are presented in Section 4. A conclusion is drawn in Section 5.

# 2. BACKGROUND

In this section, the JPEG2000 bitstream features, and the outline of using the data hiding technique for error concealment are described.

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# 2.1. JPEG2000 bitstream features

The JPEG2000 standard has a lot of nice features, such as the possibility to define Regions-Of-Interest (ROI) in an image, the error resilience and the spatial and SNR (quality) scalabilities. Scalable coding of JPEG2000 means that the images can be simultaneously available for decoding at a variety of resolutions or qualities. As we know, the last combined units of JPEG2000 code stream are packets each of which contains bit data from a specific layer, a specific component, a specific resolution, and a specific precinct. The order in which these packets are interleaved is called the progression order [8]. The standard defines four different progression orders along four axes: layer, component, resolution and precinct. The resolution-layer-component-position progression is defined as the interleaving of the packets in the following order:

for each r = 0, ..., Rfor each l = 0, ..., L-1for each i = 0, ..., Ifor each k = 0, ..., Kpacket for resolution *r*, layer *l*, component *i*,

and precinct k.

Here, *L* is the number of layers and *R* is the maximum number of decomposition levels. In general, we take I=1 and K=1. Then the coding result is that all LL subband coefficients are contained in the first L packets, shown as Figure 1.

#### 2.2. The outline of data hiding for error concealment



(b) The process of error concealment

# Fig. 3. Outline of the proposed method for error concealment using data hiding

Data hiding techniques are usually used in the digital watermarking domain for copyright protection and image authentication. The goal is to extract and to embed the feature data, and yet maintain good perceptual effects. A successful example of the data hiding technique applied to other fields is for error concealment. As discussed in Section 1, in [6], the most significant layer of a JPEG2000 bitstream is extracted as the most important feature and embedded into the least significant layer at the encoder side. Then at the decoder side, the error concealment is achieved by means of recovering the erroneous bitstream in the most significant layer using the embedded data.

Figure 2 shows the general diagram of the data hiding for error concealment. At the encoder side, some important information is extracted from an original image signal or a compressed bitstream and embedded back into it. Then, the original data with the hidden information is transmitted. At the decoder side, when an error occurs and is detected, the hidden information can be extracted for recovering the data.

# **3. THE PROPOSED METHOD**

In this section, an efficient EC method for JPEG2000 based on its features is described. It is well known that JPEG2000 is based on the discrete wavelet transform, and the low-frequency band contains big portion of

information. And the high-frequency bands contain some important edge information in different direction that will affect the reconstructed image quality directly. So for different subband, different EC method is adopted.

#### 3.1. EC for the low-frequency subband coefficients

An image is encoded through the standard JPEG2000 encoder, and the bitstream in the packet unit is generated. Suppose that the number of layer be L, the decomposed level be N, the number of precinct be 1, the number of component be 1, and that the progression order be resolution-layer-component-position. Then the first L packets, which contain all the data of the LL subband shown in Figure 1, are the most important data for hiding. Figure 3 (a) shows the procedure of data hiding. The first L packets data of a compressed bitstream is duplicated and used to replace the last bit data of the same length. In this way, the structure of the original bitstream does not change, and the generated bitstream can be transmitted and decoded in the original way.

In the error concealment process, the errors are concealed using the embedded data, shown in Figure 3 (b). During decoding, if errors are detected in the first L packets, the hidden data will be extracted and used to recover the missing data. After that, to inhibit the image deterioration caused by the data hiding, the hidden data is set to zero. The errors mainly are burst errors in the general wireless channel or in Internet, so the probability that the error position of the first L packets is the same as that of the hidden data is very small. Thus we can neglect it in this paper.

#### 3.2. EC for the high-frequency subband coefficients

In JPEG2000, the coding is carried out in bitplanes. When the SNR scalability feature is used, the error affects only the relevant bitplane during transmission. So, it is necessary to recover the significant data in the bitplane domain.

Define  $B(k)(x, y)_i^{HL}$  and  $B(k)(x, y)_i^{LH}$  as the *k*th bitplane of the wavelet coefficient at the location (x, y) in the HL<sub>i</sub> subband and the LH<sub>i</sub> subband respectively.

Their relationships with those in the other bitplanes are shown in Figure 4.

The damaged bitplanes in  $HH_i$  are set to zero directly because they have little influence on the quality of the reconstructed image. And the others will be recovered according to the following step.

**Step 1.** Detect whether a coefficient containing the damaged bitplane is on an edge. It is well known that the spatial correlation in the HL and LH subbands is maximal along the low-pass direction. So, we can use the  $HL_{i-1}$  and  $LH_{i-1}$  subbands data to determine the presence or absence of an edge. By comparing the magnitudes of the data with



Fig. 4. Recovery of the damaged bitplane using the correlative information

a threshold T, we can ascertain whether the edge is present. If it is present, we can determine there is an edge in the same spatial location at the  $HL_i$  and  $LH_i$  subbands.

**Step 2.** Estimate the damaged bitplane. If the damaged bitplane data is not on an edge, the damaged bitplane will be set to zero. Otherwise it will be set by the following formula (to recover  $B(k)(x, y)_i^{HL}$ , for example):

$$B(k)(x, y)_{i}^{HL} = (B(k+1)(x, y)_{i}^{HL'} \otimes B(k)(x+1, y)_{i}^{HL})$$
$$\oplus (B(k+1)(x, y)_{i}^{HL'} \otimes B(k)(x-1, y)_{i}^{HL})$$

Where  $\otimes$  stands for "AND",  $\oplus$  for "OR" and (.)' for "NOT".

# 4. EXPERIMENTAL RESULTS

The proposed EC methods are tested against different images, including "Lena" and "Barbara" with the size  $256 \times 256 \times 8$  bits. During the experiments the standard JPEG2000 encoder and decoder with four decomposition levels, five layered levels and the target bit rate 0.5 bpp are used. The error concealment is performed on the LL band and the third decomposition level separately. The image quality is measured in terms of the peak signal-to-noise-ratio (PSNR) between the original and the decoded image.

#### 4.1. Quality of EC for the low-frequency

Burst errors are generated in the LL band at the rate of 10<sup>-3</sup>. For each of the test images, four different cases are compared with each other: (a) Encoding with the resynchronization marker at subband level; (b) Missing wavelet coefficients are simply replaced by zeros; (c) Using the 8-neighborhood smoothing method for EC; (d) The proposed EC method is adopted. Table 1 shows the PSNR results obtained from the four cases. And the visual quality of the image "Lena" for different cases is shown in Figure 5. It is obvious that the proposed EC method behaves quite well and the reconstructed image is most similar to the image error free.

# 4.2. Quality of EC for the high-frequency

Burst errors are generated in the third decomposition level at the rate of  $10^{-3}$ . For each of the test images, also four different cases are compared: (a) Encoding with resynchronization marker at subband level; (b) Missing wavelet coefficients are simply replace by zeros; (c) Using the method in paper [7] for EC; (d) The proposed EC method is adopted. Table 2 shows the results obtained from the four cases in PSNR. Visual effects of the image "Lena" are shown in Figure 6. The proposed EC method offers some improvement over that in [7] by about 1~2 dB in PSNR. Especially for textural image, this method is much better than that in [7] for smooth images.

# 5. CONCLUSIONS

An efficient error concealment method is proposed aiming at the recovery of the missing visual information in the transmission of JPEG2000 coded images over noisy channels. The method is based on the features of JPEG2000. At the packet level of a bitstream, the lowfrequency EC algorithm is implemented by adopting the data hiding technique. And the high-frequency reconstruction is performed on a bitplane basis by utilizing the spatial correlation in intra band and inter band. The experimental results show that the proposed method is allowed for a significant improvement in the image quality.

# 6. REFERENCES

Table 1 The PSNR results obtained from the four cases described in Section 4.1

PSNR (dB) Image	Error free	(a)	(b)	(c)	(d)
Lena	31.54	14.28	17.01	27.87	30.78
Barbara	26.81	9.39	16.70	24.39	25.55

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Table 2 The PSNR results obtained from the four cases described in Section 4.2

PSNR (dB) Image	Error free	(a)	(b)	(c)	(d)
Lena	31.54	18.27	26.64	29.01	30.02
Barbara	26.81	16.08	22.82	23.81	25.98



Error free









(d) (b) (c) Fig. 5. The visual quality of the image "Lena" for different cases described in Section 4.1



Fig. 6. The visual quality of the image "Lena" for different cases described in Section 4.2