BIT-PLANE ERROR RECOVERY VIA CROSS SUBBAND FOR IMAGE TRANSMISSION IN JPEG2000

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ABSTRACT

For multimedia transmission over noisy channels, the error robustness of JPEG2000 evidently outperforms that of JPEG. Since JPEG2000 is based on discrete wavelet transform (DWT), traditional error concealment algorithms for still images in discrete cosine transform (DCT) domain are not suitable for JPEG2000. In JPEG 2000, decoding is processed bitplane by bitplane. Any data loss occurs in bitstream will affect the consequent bitplanes and their wavelet coefficients. To solve this problem, JPEG2000 VM7.2 program replaces the missing wavelet coefficients by zeros. However, the replacement may affect lots of significant non-zero coefficients such that some high frequency components are lost. In this paper, we present a novel error concealment algorithm for image transmission in bitplane base. The proposed algorithm recovers the damaged bitplanes data according to the cross subband and undamaged bitplane information. The recovered wavelet coefficients will be much similar with error-free data. The objective results show that the proposed algorithm has 3~8dB improvement than those without error resilient mechanism. In subjective view, the proposed algorithm can achieve much smoother edge on the reconstructed image by our concealment algorithm.

1. INTRODUCTION

In recent years, Internet and wireless communication have grown astronomically. However, un-reliable wireless channels may inject errors into the transmitted bit-stream. Since wireless multimedia will have much wider application in the future, error resilience issue has become a necessity for image/video transmission. In this framework, the new standard JPEG2000 is an emerging image coding standard under development by ISO/IEC Joint Photographic Experts Group (JPEG) [1]. The robust transmission issue is an important application requirement of this standard.

JPEG 2000 is based on discrete wavelet transform (DWT), quantization, and EBCOT (Embedded Block Coding with Optimization Truncation of the embedded bitstreams) algorithm [2-3]. EBCOT algorithm includes context model and arithmetic coding and post-compression rate allocation. Arithmetic coding is a variable length coding that is prone to channel or transmission error. A bit error will result in loss of synchronization at the entropy decoder such that the reconstructed image can be fully and severely damaged. In order to solve this problem, error resilience tools are included in JPEG2000. The error resilient tools adopted by JPEG2000 can be classified into two major types [4], one is *entropy coding level*; and the other is *packet level*.

In entropy coding level, it contains code-blocks, termination of the arithmetic coder for each pass, reset of contexts, selective arithmetic coding bypass, and segmentation symbol. Packet with resynchronization marker is included in Packet level. For the mobile applications, the report by ISO/IEC JTC 1/SC 29/WG 1 [5] recommends those encoding options.

The error resilient tools were introduced in JPEG2000 Verification Model (VM) [6]. Resynchronization tools enable resynchronization between the decoder and the bit-stream after residual errors were detected. The error detection tools, such as segmentation symbols termination marker, enable the decoder to detect residual bit errors. After detecting errors, the decoder must conceal the error. JPEG2000 does not standardize [7-8] any error concealment method. It is known that the bit-errors during transmission will damage some wavelet coefficients. In order to solve this problem, JPEG2000 VM7.2 program replaces the missing wavelet coefficients by zeros; however, the replacement may affect lots of significant non-zero coefficients such that some high frequency components are lost.

In this paper, we propose an error concealment algorithm, which matches practical decoding process much more, to recover damaged wavelet coefficients by some bitplane information. The basic idea is to estimate damaged bitplane data according to cross subband and undamaged bitplanes information. We obtain much smoother edge on reconstructed image by our concealment algorithm.

2. PROPOSED CONCEALMENT ALGORITHM

Most of the communication channels used in current application to transmit compressed image are error prone. JPEG 2000 error robustness is better than that of JPEG, different types of artifacts appear in wavelet based coders.

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A global view of the image is always obtained in JPEG2000, while JPEG decoder may stop decoding and empty strip in the lower part of the image.

In JPEG2000, the quality of the decoded image depends on which sub-bands are damaged. If the error occurs on higher sub-bands (high frequency) that contain the "edge" information, the decoded image will look blurred and contain ringing artifact. In fact, each sub-band block is coded by bitplane in JPEG2000. However, the bit-error during transmission will result in the loss of some wavelet coefficients relevant to a code-block in the subband. To solve this problem, we propose a concealment algorithm based on the received bitplane data to recover missing wavelet coefficients.

When the errors are detected by the error detection mechanism in JPEG2000 [6], the relevant coding pass is discarded. Thus, all wavelet coefficients of the code block will be incorrect. The simplest method is using zero to replace the missing bitplanes data. However, the upper bitplanes have much more influence to the received wavelet coefficient than the lower bitplanes when errors exist. If zero replaces the missing bitplanes data, some significant data will be lost in IDWT. Therefore, to recover the significant data on bitplane domain is necessary. We use the correlation between adjacent subbands to estimate those miss data.

The adjacent subbands are illustrated as follows. In the same decomposition level, $LH_i \leftrightarrow HL_i \leftrightarrow HH_i$ is called the inter subband, $LH_i \leftrightarrow LH_{i-1}$, $HL_i \leftrightarrow HL_{i-1}$ or $HH_i \leftrightarrow HH_{i-1}$ in different levels are called the cross subbands. The correlation factor is always greater than 0.75 and has been found by L. Atzori *etal.* [9], therefore, we can use this correlation to estimate the lost information.

2.1 The determination of zero coefficients by zerotree technology

Zerotree exploits the interdependence of wavelet coefficients in different subbands. The coefficients in different bands are organized into quadtree, so that a single coefficient in band LH_i (or HL_i or HH_i) is the parent of the four coefficients in band LH_{i-1} (or HL_{i-1} or HH_{i-1}) in the same spatial location. We observe that the zerotree structure can be applied to any set of zero values arranged as a quadtree. Based on the above description, consequently, the first step of our proposed algorithm is that the loss bitplane data are set to zero when the parent of wavelet coefficient is zero.

2.2 Error concealment via cross subband data

Because of spatial correlation of the cross subband is very high, in the concealment framework, we estimate the damaged bitplane data from the cross subband information corresponding to the same spatial location. Suppose there is a damaged bitplane $Bp_{i-1}[k][s][t]$, we consider its upper bitplane $Bp_{i-1}[k+1][s][t]$ and its cross subband's corresponding bitplane ($Bp_i[k][s][t]$) and upper bitplane $Bp_i[k+1][s][t]$ as shown in Fig. 1. It is noted that the latter three bitplanes are undamaged or have been concealed. The main reason is that the damaged coefficients are similar with those in the cross subband. However, they are similar only, but not the same completely [9]. In order to compensate the difference, we add the upper bitplane information $Bp_{i-1}[k+1][s][t]$ and $Bp_i[k+1][s][t]$. For instance, if $Bp_i[k][s][t]$ is 1, $Bp_i[k+1][s][t]$ is 0 and $Bp_{i-1}[k+1][s][t]$ is 1, then $Bp_{i-1}[k][s][t]$ should be set to 0. In the special case, that $Bp_i[k][s][t]$ is 1, $Bp_i[k+1][s][t]$ is 1 and $Bp_{i-1}[k+1][s][t]$ is 1, in order avoid the overflow in IDWT, then $Bp_{i-1}[k][s][t]$ should be set to 0. The strategy of concealment of the damaged bitplane information can be represented by the following formula.

$$Bp_{i-1}[k][s][t] = \left(Bp_i[k+1][s][t] \otimes \left(Bp_{i-1}[k+1][s][t]\right)' \right) \oplus \left(\left(Bp_{i-1}[k+1][s][t]\right)' \otimes Bp_i[k][s][t] \right)$$

where $\otimes$ is "AND", $\oplus$ is "OR" and $(\cdot)'$ is the inverter. Furthermore, k and i denote the location of the bitplane, and the level of subband, respectively. s and t denotes the coordinate of the lost pixel.

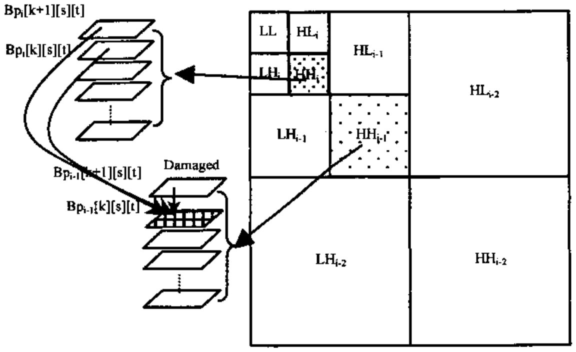

Fig. 1 Recover lost bitplane data by cross subband

We can summarize the proposed concealment algorithm to the following procedure.

Step 1. Error detection: When the compression image bitstream comes into the decoder, every pass will be decoded. Then errors can be detected by the error resilience mechanism in JPEG2000. If errors are detected, the relevant bitplane data will be discarded.

Step 2. The determination of zero coefficients by zerotree technology: If the parent wavelet coefficient is zero, according to subsection 2.1, the lost bitplane data are set to zero. Otherwise, go to next step.

Step 3. Error concealment via cross subband data: We can estimate the damaged bitplane data from subsection 2.2.

Step 4. Bitplane data assembly: The data from the above two steps are collected to the coefficients for IDWT and reconstructed image.

The above procedure is also illustrated by the flowchart in Fig.2.

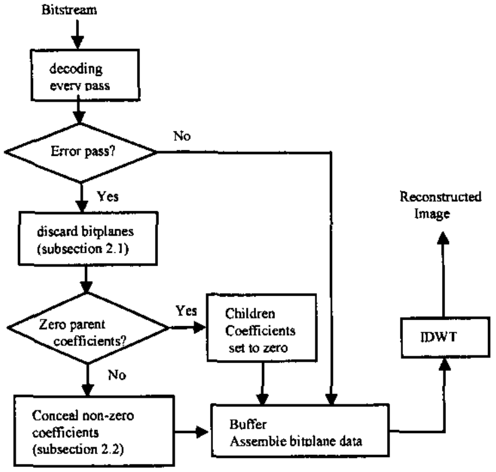

Fig. 2 The flow chart for the recovery of damaged bitplane

3. SIMULATION RESULTS

The proposed algorithm is tested with several pictures characterized by different bit-rates. The simulation includes the following pictures: "Lena," "Baboon," "Jet," "Barbara," and "Pepper" with 256×256 pixels. During the experiments, three decomposition levels are used. For each test image, we compare three different cases: (1) encoding with resynchronization marker at subband level, when the error occurs, all DWT coefficients in this subband will be affected. However the error will not propagate when the resynchronization marker is detected. (2) encoding with error resilient properties, such as, resynchronization marker for each subbands, segmentation marker for each bitplane, and termination at each coding pass. When the error occurs, DWT coefficient below the error bitplane will be affected. In decoding with error detection mechanism those missing wavelet coefficients are simply replaced by zeros. (3) the procedure is the same as (2) in encoding process, but in decoding process, the proposed error concealment algorithm is added.

Fig. 3 shows the performance obtained from the three cases when the compressed bit-streams by 5/3 filter are corrupted with burst error of BER 10e-3 on the second decomposition levels HH_2 subband. The case (2) with inserting resynchronization marker at bitplane level has improved 3~5dB in error resilient properties for each bitplane than case (1). The case (3) with our error concealment algorithm in decoding will have 0.6-3 dB improvements than case (2) that replaces the missing wavelet coefficients by zeros. Fig. 4 shows the objective results of the "Lena" image for various bit-rates. We find that the lost wavelet coefficients filled by zeros will be not suitable in low bit-rate. The comparisons of the results among the above three cases are shown in Fig. 5. The reconstructed images in case (1) and (2) look blurry and contains ringing artifact. We have obtained the smoother edge by adding our concealment algorithm, for example, in "Lena" face, arm and mirror edge. That is because we have much more correct high frequency coefficients for IDWT in our proposed algorithm.

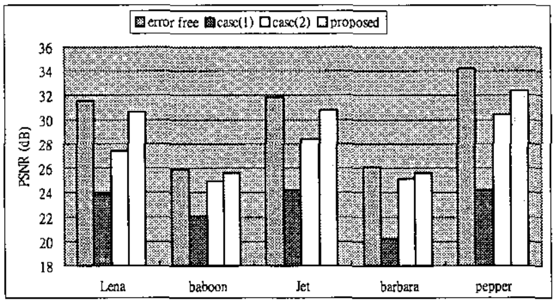

Fig. 3 The result by test images, BER=10e-3, bit-rate=0.5bpp

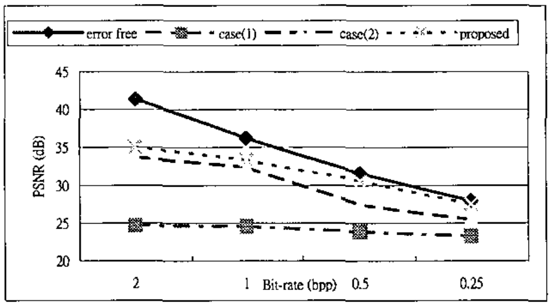

Fig. 4 Objective results of the "Lena" image for various bit-rates

4. CONCULSION

In this paper, we have proposed a new technique to improve the error resilience ability for JPEG2000. The proposed approach utilizes cross subband and undamaged bitplane information instead of replacing the missing wavelet coefficients by zeros to recover damaged high frequency wavelet coefficients such that the recovered wavelet coefficients will be much similar with noise-free data. The experiments have shown that we have the objective result with 3~8 dB improvement than those without error resilient mechanism and the subjective result with much smoother edge on the reconstructed image by the proposed concealment algorithm.

5. REFERENCES

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(a) (b)

(c) (d)

Fig. 5 The subjective results by BER=10e-3 bit-rate=0.5bpp (a) reconstructed image by error free (b) error resilience only by resynchronization marker (c) missing wavelet coefficients replaced by zeros (d) reconstructed image by our proposed algorithm