Lossless data hiding using bit-depth embedding for JPEG2000 compressed bit-stream

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Abstract

We have proposed a reversible information hiding for binary images. In this paper, we presents a lossless data hiding method for JPEG2000 compressed data based on the reversible information hiding. In JPEG2000 compression, wavelet coefficients of an image are quantized, therefore, the least significant bit plane (LSB) can be extracted. The proposed method recovers the quantized wavelet coefficients of cover images from stego images. To realize this, we embed not only secret data and the JBIG2 bit-stream of a part of the LSB plane but also the bit-depth of the quantized coefficients on some code-blocks. Experimental results demonstrate the feasibility of application of the proposed method to image alteration detection for JPEG2000 compressed data.

1 Introduction

Almost data embedding techniques, directly or indirectly, modify the pixel value of cover images to insert the additional information, hence, distort the image. Although the distortion is quite small, it may not be acceptable for the filed where raw data is required to analyze, process or extract important information , such as legal and medical imaging. For such purpose, reversible information hiding has been proposed[3][6]. Reversible information hiding, which is also called lossless data embedding, embeds additional information into digital images in a reversible way. Reversible in this context means that one can remove the embedded data to restore the original image. Several techniques in the research field refereed above are applied in spatial domain in gray-scale images or full color images. For binary images, our group [4] have presented a lossless data hiding method[4].

Tian [5] and Xaun et. al[7] proposed lossless data hiding methods based on integer wavelet transform, which allows for perfect invertible with finite precision arithmetic. In this paper, we present a reversible information hiding of JPEG2000 compressed data having the irreversible wavelet transform mode. This method is based on our previous work of reversible data hiding for binary images. In JPEG2000, the wavelet coefficients are quantized, hence, a bit-plane structure is extracted from the coefficients. For compressing the least significant bit (LSB) plane extracted from the bit-plane structure, the JBIG2 lossless compression scheme is used to make space to insert an additional information (secret data). The compressed data is added to the bit-stream of secret data, and then it is embedded into the LSB plane by replacing pixel value with the bit-stream. Besides JBIG2 bit-stream and secret data, the bit-depth of quantized wavelet coefficients on some code-blocks will also be embedded to correctly extract the LSB plane of stego images.

2 Background

2.1 JPEG2000 compression standard[1][2]

The core structure of the JPEG2000 encoder which is shown in Figure 1 follows a typical sequence of operations used in a transform coding scheme, which consists of pre-processing, transformation and entropy coding. Within the pre-processing module, the original image with unsigned data is first DC level shifted. Then the component transformation can be carried out if the original image has multiple components.

Image components can be partitioned into titles, which are rectangular non-overlapping blocks, and the standard works on the tiles. The forward discrete

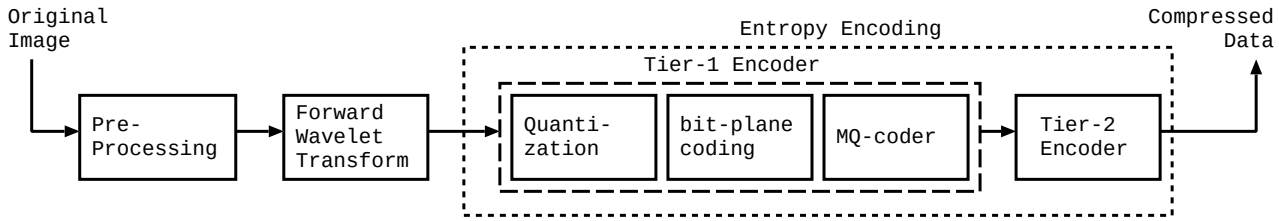


Figure 1. Core structure of the JPEG2000 encoder.

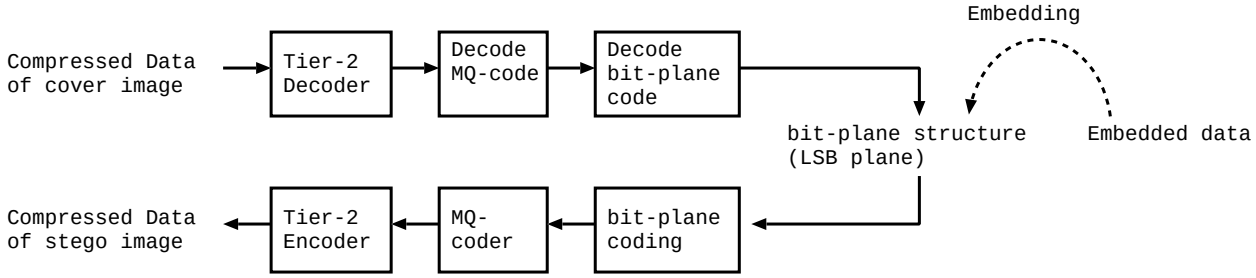


Figure 2. Block diagram of the embedding in the proposed method.

wavelet transform which can be irreversible or reversible is applied on each tile-components. The tile is decomposed in different resolution levels. The calculated wavelet coefficients are then entropy coded.

We now briefly describe the entropy coding which is grouped two tiers: tier-1 and tier-2. In the tire-1 encoder, the subbands of wavelet coefficients are quantized and collected into rectangular arrays of "code-blocks." The quantized coefficients on each code-block are regarded as having a bit-plane structure. Each coefficients bit in the bit-plane is coded in only one of three coding passes, and the symbols that it produces are coded using the MQ-coder. In the tier-2 encoder, the codestream obtained by the tier-1 encoder is carefully organized to target a defined bit-rate and construct a flexible file format . Note that this entropy coding is based on EBCOT (Embedded Block-based Coding with Optimized Truncation) algorithm. It should be noted that each code-block has a bit-depth to represent the quantized wavelet coefficients contained in its code-block, and the bit-depth would vary on each code-block.

The decoding process in JPEG2000 is basically the reverse of the encoding one.

2.2 Reversible information hiding for binary images[4]

Embedded data is hidden into noisy blocks on cover binary images. The noisy blocks are extracted by the simple thresholding with threshold α_{TH} of the measure called complexity defined to binary images. Only half of the all pixels in noisy blocks is replaced with the bitstream of embedded data. Pixels used in the embedding are corresponding to white pixels (or block pixels) on checkerboard patterns. In other words, cover binary images are regarded as consisting two types of pixels: *replaceable pixels* and *unusable pixels* which correspond to white pixels and black pixels on checkerboard patterns, respectively.

In order to recover original images, we need to embed the original information of replaceable pixels and make space for secret data, therefore we compress cover binary images that all unusable pixels are set to 0 (or 1) using the JBIG2 compression scheme. We embed the compress data and secret data into cover binary images.

The embedding in this method is performed by replacing replaceable pixels with the embedded bitstream. The complexity of the noisy block may become smaller than α_{TH} by the embedding. In that case, we apply the conjugate operation to it to keep the the complexity of the block being greater than α_{TH}. We need to keep track, for each block, of whether the con-

jugate operation had been applied using *a conjugation flag*. We make the value of one of replaceable pixels to the flag.

At the receiver side, one can extract the embedded bit-stream from noisy blocks by scanning the image in the same order in embedding. For the blocks to which conjugate operation applied, we apply conjugate operation prior to extracting embedded information. The extracted bit-stream is separated into the bits of secret data and the JBIG2 bit-stream. The bit-stream is decompressed to reveal the original pixel. The original binary image can be completely restored by replacing the replaceable pixels of the stego image with one of the decompressed image.

3 Proposed method

In the proposed method, we assume that the data of cover image is given as a JPEG2000 compressed bit-stream and perform the embedding procedures to the bit-stream, as a consequence of this, stego images are produced as a JPEG2000 compressed bit-stream. The quantized wavelet coefficients in the cover image are completely recovered from the stego image.

3.1 Embedding

The block diagram of the encoding in the proposed method is illustrated in Figure 2. In JPEG2000, the bit-depth to represent quantized wavelet coefficients is allowed for code-blocks to vary within 32 bits including plus minus sign, and this depth is determined after the tier-2 encoding. Therefore, by using the bit-depth information, we can extract the least significant bit from each wavelet coefficients encoded in the JPEG2000 bit-stream.

Basically, we apply our reversible information hiding method for binary images described before to the LSB plane extracted from quantized wavelet coefficients, which is regarded as a binary image. However we have found a problem that the bit-depth of code-blocks containing wavelet coefficients value of 0, 1 or -1 increases by the embedding through several experiments. This makes us to extract embedded information incorrectly.

In order to solve the problem, we need to embed not only JBIG2 bit-stream and secret data but also the bit-depth of the code-blocks. The embedding procedures in detail are as follows. Firstly, we collect the bit-depth information of code-blocks on all resolution of subbands except for the lowest one, and then we embed it into the region where code-blocks are on the lowest resolution of subbands. For the rest of pixels, we embed the JBIG2 bit-stream and secret data.

3.2 Extraction and recovering original wavelet coefficients

After Tier-1 decoding, quantized wavelet coefficients are reconstructed, and then we divide the coefficients into code-blocks which is the same size in encoding. From the code-blocks where are on the lowest resolution of subbans, we extract the original bit-depth information of the rest of code-blocks,and then, by using the bit-depth information, the embedded bit-stream consisting secret data and JBIG2 bit-stream is extracted.

The recovering of the original wavelet coefficients is as follows. The extract JBIG2 bit-stream is firstly decoded, and then the pixel value located on changeable pixels of the decoded image is replaced. After this replacement, we completely reconstruct the original quantized wavelet coefficients.

4 Experimental results

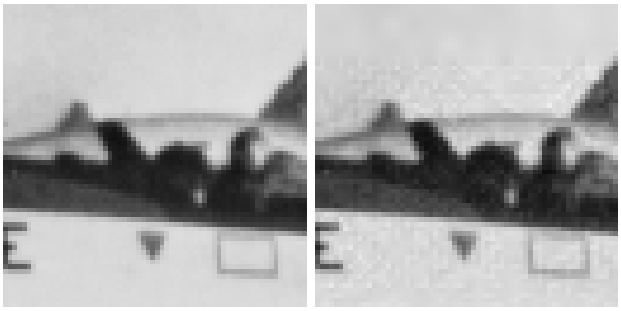
We have implemented the proposed algorithm in the JJ2000 software. To illustrate the performance of our method, we embedded four JPEG2000 test-images *Airplane*, *Bridge*,*Barbara* and *Lena* (8bpp, 512×512) with 8×8 block size using to calculate the complexity of binary images and 5/112 complexity threshold ($=\alpha_{TH}$) and a random bit-sequence embedded as a secret data. A 5-scale wavelet transform with the Daubechies 9/7 filter was applied to the images, therefore 64×64 and 32×32 of code-blocks in size were selected. The number of code-blocks on the images was 70. The 4 code-blocks on the lowest resolution of subband were used to embed the bit-depth of the rest of code-blocks. Therefore, we needed to embed 330 bits ($= 66 \times 5$ bits) to keep the depth information.

Table 1 shows the results obtained by the experiment. PSNRc and PSNRs represent PSNR of cover image and one of stego image with the JPEG2000 compressed, respectively. The quality of whole image is almost acceptable for the test images we used in the experiments. However, uniform regions could be slightly distorted with sandy noise added. In addition, the image degradation of zoomed regions may be recognized. Figure 3 shows an example of this degradation.

The proposed method is able to apply to image alteration detection of JPEG2000 compressed data. The embedded information used in the experiments is quite large compared by the number of bits to represent hash value, such as SHA-1 which produces a message digest that is 160 bits long. Because whole LSB plane was used in the experiments, we certainly avoid the image degradation by using only a part of the LSB plane for the embedding.

Table 1. Experimental results for five test images.

Image	Cover size [byte]	Stego size [byte]	PSNRc [dB]	PSNRs [dB]	JBIG2 of LSB plane [byte]	secret data [bit]	Embedding rate [%]
Airplane	33467	49394	41.39	36.84	6230	9166	22.16
Bridge	32604	49394	30.53	27.02	8276	9502	29.15
Barbara	32641	49014	37.96	33.61	7294	4198	24.08
Lena	33150	50471	40.43	36.38	6195	11814	23.26



(a) cover image (b) stego image

Figure 3. Image degradation (Airplane).

5 Conclusion

We have proposed a technique for lossless data hiding for JPEG2000 compressed bit-stream. The bit-depth of some code-blocks are embedded. After the extraction steps, the secret data will be extracted and retrieve a bit-plane structure of quantized wavelet coefficients, which is exactly the same as the original bit-stream. The experimental results show the feasibility of application of the proposed method to image alteration detection for JPEG2000 compressed data.

References

[1] D. Chai and A. Bouzerdoum. JPEG2000 image compression: an overview. In *Proc. of the Seventh Australian and New Zealand Intelligent Information Systems Conference*, pages 237–241, 2001.

[2] C. Christopoulos, A. Skodras, and T. Ebrahimi. The JPEG2000 still image coding system: an overview. *IEEE Transactions on Consumer Electronics*, 46(4):1103–1127, November 2000.

[3] M.Goljan, J. J. Fridrich, and R. Du. Distortion-free data embedding for images. *LNCS 2137*, pages 27–41, 2001.

[4] S. Tanaka, M. Niimi, and H. Noda. A Study on Reversible Information Hiding using Complexity Measure for Binary Images. In *Proc. of Intelligent Information Hiding and Multimedia Signal Processing*, volume II, pages 29–32, 2007.

[5] J. Tian. Wavelet-based reversible watermarking for authentication. In *Proc. of the SPIE -Security and Watermarking of Multimedia Contents IV-*, volume 4675, pages 679–690, 2002.

[6] J. Tian. Reversible data embedding using a difference expansion. *IEEE Transactions on Circuits and Systems for Video Technology*, 13(8):890–896, 2003.

[7] G. Xuan, Y. Q. Shi, C. Yang, Y. Zheng, D. Zou, and P. Chai. Lossless data hiding using integer wavelet transform and threshold embedding technique. In *Proc. of IEEE International Conference on Multimedia and Mxpo*, pages 1520–1523, 2005.