A method for embedding binary data into JPEG2000 bit streams based on the layer structure

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ABSTRACT

A method for embedding binary data into JPEG2000 bit streams was developed. Using the method, a decoder can perfectly extract embedded data as well as it can when using the conventional methods. Moreover, by exploiting the layer structure of a JPEG2000 bit stream, the method effectively suppress the quality deterioration of a reconstructed image due to embedding, and it can perform embedding and extracting independently of image coding. The length of data that can be embedded and the deterioration of the reconstructed image due to embedding were simulated.

1 Introduction

Watermarking techniques that embed information into digital images imperceptibly has been studied extensively recently [1–7]. One of the applications of such a watermarking techniques is copyright protection [6]. Illegal use of digital images is discouraged by means of embedded identification information. An other application is data embedding for multiplexing other contents in a digital image so that an image and other contents altogether. This paper focuses on a watermarking technique for the latter application.

In this application, embedded data need not to be in hidden form and there are various objective contents for embedding, for example, index label [2] and audio data. In video coding, errors can be concealed by embedding motion vectors into bit streams [8].

As a method of data embedding for multiplexing other contents, it is essential to embed binary data into a digital image and extract them perfectly. It is also required that an image with embedded data can be decoded by a general decoder. The conventional methods, which targets JPEG images, satisfies these points [1, 2].

In the current work, a more advanced method for data embedding that targets JPEG2000 [9–12] coded images was developed. This method embeds data into a JPEG2000 bit stream by overwriting certain parts of the bit stream. The part to be overwritten is selected adequately by utilizing the layer function of the JPEG2000 coding system. While the developed method satisfies the requirements for data embedding as mentioned above, additional features, which were not available with the conventional methods, are provided. One of the features is that the length of the image data is not changed by embedding. It also results that the embedding process can be performed independently of the encoder and decoder of an image coding. The other feature is that the deterioration of the reconstructed image due to embedding is suppressed effectively.

2 JPEG2000 coding [9–12]

2.1 Review of coding procedure

Figure 1 is a block diagram of a JPEG2000 encoder. An input image is decomposed into sub-bands by a discrete wavelet transform and the wavelet coefficients of each sub-band are quantized. After quantization, each sub-band is divided into rectangular blocks, called code-blocks, which form the independent input to coefficient bit modeling and arithmetic coding. A separate arithmetic code is generated for each code-block. The arithmetic code for each code block has a lot of truncation points so that it can be truncated into a various lengths. One truncation point is allocated for each code blocks subject to a target bit rate. After that, the layer structure is formed for scalability of a bit stream. Since the developed method exploits the layer structure, we explain it in detail.

2.2 Layer formation

Figure 2 shows the structure of a JPEG2000 bit stream. A global bit stream consists of a header and a sequence of layers. Each layer includes a part of coded code blocks so that it successively improves the image quality. The most significant layer comprises the most significant contribution to image quality and the following layers increment image quality successively. Thus, the decoder can decode a bit stream with improving image quality progressively.

Figure 3 shows a conceptual view of the layer structure. Figure 3(a) is a bit stream whose rate is 1.0 bits/pixel. It has two uniform layers, namely each layer has a rate of 0.5 bits/pixel. This bit stream can be decoded by the decoder with two steps of image quality improvement. Furthermore, the lower rate bit stream (Figure 3(b)) can be generated by truncating the latter layer of the longer bit stream (Figure 3(a)). The lower rate bit stream generated in such a way is nearly same as the bit stream encoded to have the lower rate

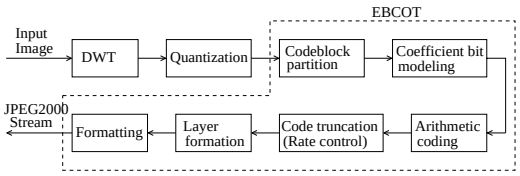

Figure 1: JPEG2000 encoder.

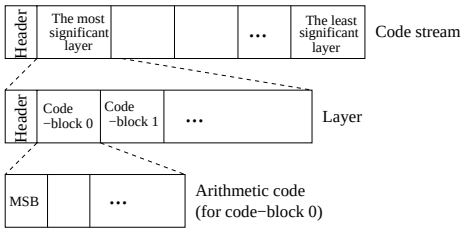

Figure 2: Structure of a JPEG2000 bit stream.

originally. It should be noted that the number of layers and the length of each layer could be assigned arbitrarily in a JPEG2000 encoder.

3 New embedding method

The developed method for embedding data into a JPEG2000 bit stream is designed to satisfy the following conditions. Note that the conditions (a) and (b) were satisfied by the conventional method, yet (c) and (d) were not. Condition (c) states that embedding and extracting can be performed independent of image coding.

(a) The embedded data can be extracted perfectly under a lossy coding scheme.

(b) A general decoder can be used.

(c) The length of the bit stream is not changed.

(d) The deterioration of a reconstructed image due to embedding is suppressed.

First, we explain the embedding process in the developed method. Then we explain the decoding of a bit stream containing embedded data. We show that the developed method satisfies the conditions. In addition, we mention the affair concerning marker codes that is important for the embedding and extracting.

3.1 Data embedding into a JPEG2000 bit stream

In the new method, first, an image is encoded into JPEG2000 bit stream with two layers by means of a general JPEG2000 encoder. Next, the encoded bit stream of the latter layer is scanned in backward order and replaced with the data that we want to embed (see Figure 4.). One byte of embedded data replaces one byte of the original bit stream. This means that the length of the bit stream is not changed. If the latter layer has surplus bytes to be replaced, they are left alone.

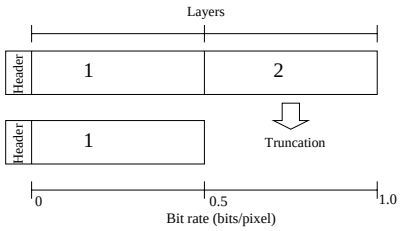

Figure 3: Layer truncation. (The latter layer of a double-layered bit stream was truncated.)

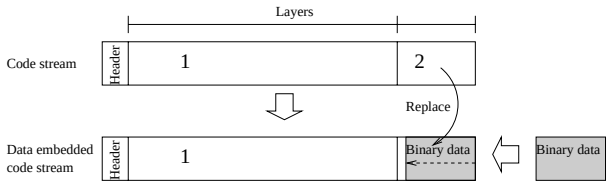

Figure 4: Data embedding to the latter layer. (The shaded area is replaced with embedded data.)

The maximum length of data that can be embedded depends on the length of the latter layer of a double-layered bit stream, so the length of the latter layer is made longer than that of the data to be embedded.

3.2 Decoding of a JPEG2000 bit stream containing embedded data

A JPEG2000 bit stream containing embedded data can be decoded by a general JPEG2000 decoder. Depending on knowledge of embedding, i.e., the fact that the developed method was applied, and on the necessity of extracting embedded data, there are three types of decoding as explained follows.

(A) Decoding without knowledge of embedding

Even if the decoder has no knowledge of embedding, a JPEG2000 bit stream containing embedded data can be decoded because the header information and the length of bit stream are not changed, namely, the bit stream is compatible with JPEG2000 (Figure 5). The embedded data are decoded as noise, so some quality deterioration of a reconstructed image occurs, yet the deterioration is not serious since the latter layer makes a less significant contribution to image quality.

(B) Decoding with the knowledge of embedding

When the decoder has knowledge of embedding, the quality deterioration due to embedded data can be further reduced by truncating the latter layer. As shown in figure 6, the latter layer, which contains the embedded data, is truncated. A truncated bit stream that has a shorter length is thus generated. The reconstructed image from the truncated bit stream is usually better than that from the original bit stream which including the embedded data, because noise come from decoding the embedded data no longer appears.

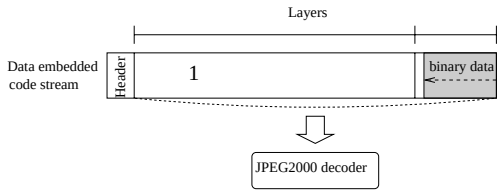

Figure 5: Decoding without knowledge of embedding. (Type A: the whole bit stream was decoded.)

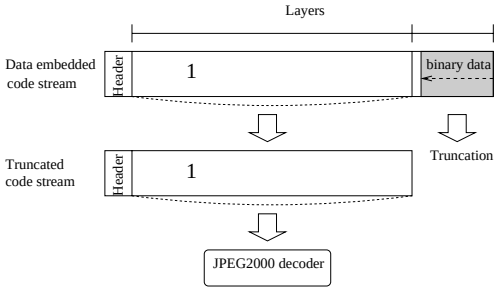

Figure 6: Decoding with knowledge of embedding. (Type B: only the first layer was decoded.)

(C) Extracting of embedded data

If the decoder has knowledge of embedding, the embedded data can be extracted by scanning the bit stream of the latter layer in backward order as shown in Figure 7. The length of the embedded data should be known to the decoder for extracting the embedded data correctly unless the length of the latter layer is the same as that of the embedded data. In this case, the reconstruction of the image can be done in the same way as type B described above.

3.3 Avoidance of embedding fake marker codes

When embedding data into a JPEG2000 bit stream, we should take into account that a JPEG2000 coder uses codes ranging from 0xFF90 to 0xFFFF, which do not arose in the arithmetic encoder used in JPEG2000, as the special maker codes that have special meaning (e.g., 0xFFD9 means "End of code"). If the data to be embedded contains a bit stream equal to such codes, (in other words if fake marker codes are included in the embedded data,) correct decoding of a bit stream with embedded data will be occasionally prevented. Therefore, the data must be transformed without including such codes before embedding.

One possible way to do this kind of transform is to apply arithmetic encoding, same as that used in a JPEG2000 coder, to the data before embedding. In the extracting, the original data can be reconstructed by arithmetic decoding.

4 Simulation

We demonstrated the effectiveness of the developed embedding method by simulation. The method was applied to the standard image "Lena" (256 grayscale, 512×512, 262,144 bytes). The image coding was done by a five-level decomposition/composition process based on two-channel filter banks with Daubechies 9/7 bi-orthogonal wavelet filter running under the JPEG2000 verification model 7.0 [13]. The target bit rate was 1.0 bits/pixel (32,768 bytes).

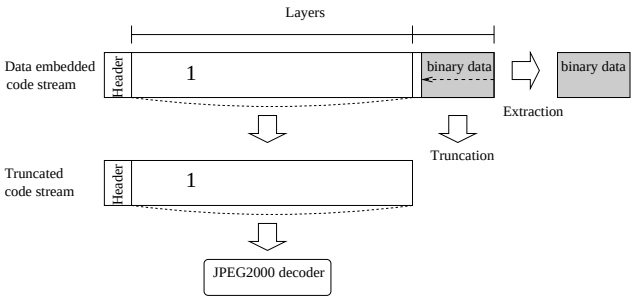

Figure 7: Extracting of embedded data. (Type C: The shaded area was extracted as the embedded data and the truncated bit stream was decoded.)

4.1 Available length of embedded data

We determined how much data can be embedded into a JPEG2000 bit stream by the developed method. Figure 8 shows the relationship between the bit rate of the latter layer and the maximum length of the embedded data. As shown in the figure, the method can embed various lengths of data. This is because the length of each layer can be assigned arbitrarily within the whole length of a bit stream in a JPEG2000 encoder and because the maximum length of embedded data depends on the length of the latter layer of a double-layered bit stream.

4.2 Image deterioration due to embedding

The image deterioration due to embedding in the developed method was measured in terms of peak signal-to-noise ratio (PSNR) between the original image and the reconstructed image. Higher PSNR means lower deterioration.

First, the deterioration due to embedding by the new method is compared to that of the conventional methods based on JPEG coding [1] under the same condition. We assumed that the decoder has knowledge of the embedding, i.e., it corresponds to type B mentioned in **3.2**. The result of the comparison is shown in Figure 10. It is clear that the new method entirely outperforms the conventional method in terms of PSNR.

Next, the PSNR against the length of the embedded data when a bit stream containing embedded data is decoded with a general JPEG2000 decoder was measured. The two ways of decoding, types A and B described in **3.2**, were compared. Type A decodes the whole bit stream without the knowledge of embedding. Type B truncates the latter layer of the double-layered bit stream before decoding with utilizing the knowledge of embedding. The results are shown in the Figure 9. It is clear that type B demonstrates better performance than type A. This results shows that further suppression of the deterioration is possible by the new method if the decoder has the knowledge of embedding.

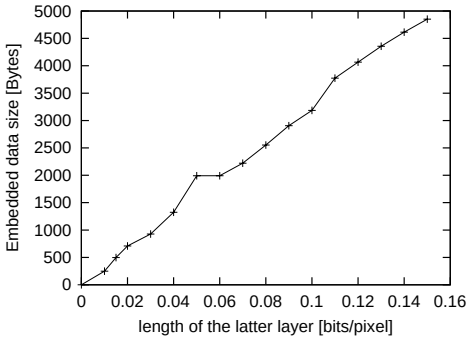

Figure 8: Available size of embedded data vs. the length of the latter layer.

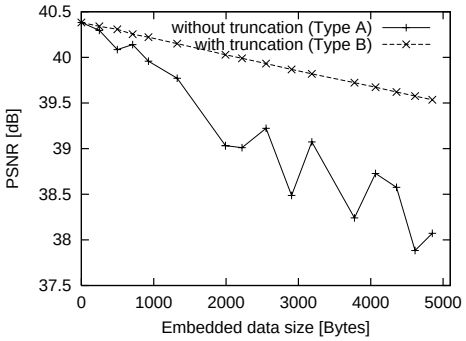

Figure 9: Comparison of type A and type B of decoding. (PSNR corresponding to the length of embedded data.)

The above results show that the new embedding method is capable of embedding various lengths of data and can suppress the deterioration due to embedding effectively.

5 Summary

We developed a method of embedding binary data into JPEG2000 bit streams. This method exploits various capacity of the JPEG2000 coding system, such as layer structure, so that it can effectively embed data into a digital image. Simulation results demonstrated the effectiveness of the new method.

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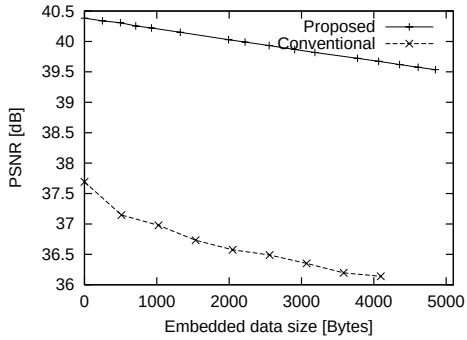

Figure 10: Comparison of the new method and the conventional method. (PSNR corresponding to the length of embedded data.)