An Image Estimation Method by Header Information in JPEG 2000 Codestreams and Its Application to Image Identification

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***Abstract*—We propose an image estimation method by using header information in JPEG 2000 codestreams. Some information is directly extracted from header parts, and is used to estimate an original image without using any body data. From the estimated images, image signature values, which are utilized in MPEG 7 for image retrieval or image identification, are calculated as an image similarity index. Moreover, the relationship between estimated images and original ones are considered with the object of both image identification in the compressed domain and secure image management, by using the signature values. The experimental results show the effectiveness of the proposed method.**

I. Introduction

The use of digital images and video sequences has greatly increased recently because of the rapid growth of the Internet and multimedia systems. It is often necessary to identify a certain image in a database that has a large number of digital images in various types of the applications of images/videos. The image database generally consists of images in a compressed form to reduce the amount of data. In this paper, ”Identification” is defined as an operation for finding an image that is identical to a given original image from an image database.

JPEG 2000 has been officially selected as the standard compression/decompression technology for digital cinema by the Digital Cinema Initiatives consortium[1]–[2]. Several methods have been developed for identifying compressed images to handle efficiently a large number of frames. Codestrem-based identification methods for JPEG 2000 images have also been considered[3]-[6]. These methods achieve fast and precise identification because they use the number of zero-bit-planes(NZBP), which is obtained by only parsing the header part of a JPEG 2000 codestream, as the feature for the identification. However, they have two issues that are not only limited to the identification among images with a same original, but also not secure identification. Several studies have been developed for image encryption and image identification in the encrypted domain[7]–[10]. In addition, Refs.[11] and [12] note that leaving the headers in plaintext severely compromises the security. However, the importance of header parts in codestreams has not been considered yet from a viewpoint of image identification or image retrieval in addition to secure image management.

To overcome such a situation, in this paper, we propose an image estimation method by using header parts in JPEG 2000 codestreams. Some information is direct extracted from header parts, and is used to estimate an original image, and image signature values[13] as an image similarity index are calculated by using the estimated images. The relationship between estimated images and original ones are considered and the importance of header parts in JPEG 2000 codestreams is discussed. In our method, we achieve not only the image identification among images with a same original but also the image retrieval among similar images such as neighbor frames in a same scene in a video sequence. Namely, our method make class identification possible.

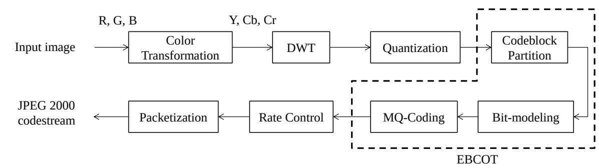


Fig. 1. Block diagram of JPEG 2000 encoder.

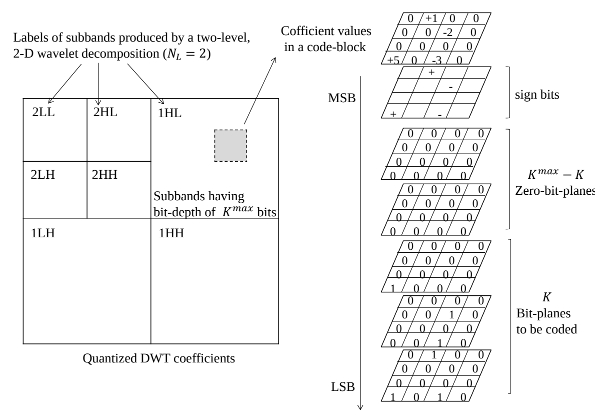


Fig. 2. Bit-plane decomposition and sign-magnitude. representation of DWT coefficients in code-block. A zero-bit-plane is a special bit-plane in which the samples are all zeros. Zero-bit-planes are arranged from the MSB to the LSB level.

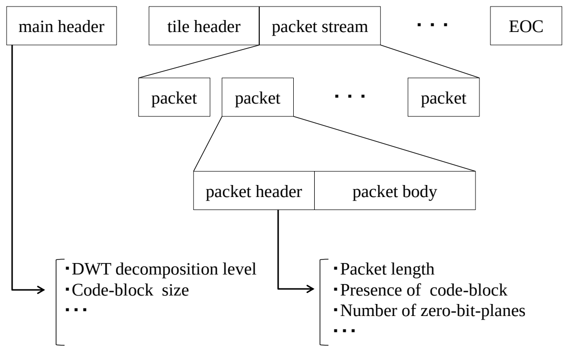


Fig. 3. Structure of JPEG 2000 codestreams.

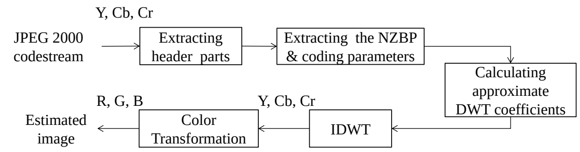


Fig. 4. Block diagram of the proposed estimation.

NZBP	0	1	2	···	6	not included	
DWT coefficients	1	0	0		0	0	MSB
	?	1	0		0	0	
	?	?	1		0	0	
	?	?	?		0	0	
	?	?	?		0	0	
	?	?	?		0	0	
	?	?	?		1	0	LSB

Fig. 5. The relation between the NZBP and DWT coefficients. The value of 1 means that not all samples of the bit-plane in a code-block are equal to 0. The question mark (?) represents that sample values of the bit-plane are unknown.

II. JPEG 2000 AND NUMBER OF ZERO-BIT-PLANES

A. Definition

Fig. 1 shows a block diagram of the JPEG 2000 encoder. JPEG 2000 uses a bit-plane coding architecture summarized as follows. As outlined in Fig. 2, quantized DWT coefficients are represented in a sign-magnitude form. The sign bit-plane is at the MSB level, and the magnitude bit-planes are beneath it. The number of samples in each bit-plane is equal to the size in the code-block, and all sample values in the bit-plane are either 0 or 1. Let the K^{max} denotes, the number of bits required to represent all quantized coefficients. The block coder for JPEG2000 first determines the number of bits, $K \leq K^{max}$, that are needed to represent the quantized magnitudes. The encorder ideally finds the smallest such *K*. The difference between$K^{max} - K$ is called the “number of zero-bit-planes(NZBP)” and is defined by

$$N_{zbp} = K^{max} - K. \tag{1}$$

The NZBP, N_{zbp}, represents the number of the most significant magnitude bits that is skipped to encode with the encoder. The decoder will take this to be zero for all samples. The remaining *K* magnitude bits must be explicitly coded. A code-block in which all the bit-planes are zero-bit-planes in the JPEG 2000 standard is defined as “not included” because the code-block does not contain any data to be encoded.

B. Effect of changes in coding rate on NZBP

Since the coding-rate in JPEG 2000 is normally controlled by discarding the MQ-encoded codestreams from LSB to MSB, it fundamentally has no effect on the NZBP even if the coding rate changes. However, the number of “not included” code-blocks may change if the coding rate changes. The NZBP is part of the header information of JPEG 2000 codestreams. This information is easily obtained by parsing the header parts of JPEG 2000 without needing heavy EBCOT decoding.

III. PROPOSED METHOD

Fig. 3 shows the structure of JPEG 2000 codestreams. We use some information in the main header part and the packet header parts to calculate approximate DWT coefficients and estimate images encoded by JPEG 2000. Fig.4 is a block diagram of the proposed estimation. The procedure is summarized as follows.

- Step1. The NZBP is extracted from packet header parts and coding parameters such as DWT decomposition level and code-block size are extracted from the main header respectively.
- Step2. Approximate DWT coefficients are calculated by using the NZBP and the coding parameters.
- Step3. The inverse discrete wavelet transform (IDWT) is carried out to estimate Y, Cb and Cr pixel values by using the approximate DWT coefficients.
- Step4. Y, Cb and Cr pixel values are transformed into R, G and B ones.

Next, Step2 will be explained in more detail.

A. The formula for calculating approximate DWT coefficients

As shown in Fig.5, the NZBP of each code-block is related to the magnitude of DWT coefficients in the code-block. Note that the NZBP shows the number of bit planes with zero values counted from the MSB, as shown in Eq.(1). Therefore, when the NZBP has a small value in a code-block, the DWT coefficients in the code-block have large values. we also see that there is at least one sample with the value 1 in the $(N_{zbp}+1)$th bit-plane, although any sample values in other bit planes can not be defined from the NZBP. Considering these properties of the NZBP and quantization step sizes, the formula for calculating approximate DWT coefficients in a code block i, which is in a subband b, is proposed for JPEG 2000 lossy compression as follows.

$$W_i = \begin{cases} 2^{-(N_{zbp}-N_L+n_b)} = 2^{-N_{zbp}}, & \text{(LL)} \\ 2^{-(N_{zbp}-1-N_L+n_b)}, & \text{(LH, HL)} \\ 2^{-(N_{zbp}-2-N_L+n_b)}, & \text{(HH)} \\ 0, & \text{(NZBP is "not included")} \end{cases} \tag{2}$$

where N_L is the total number of decomposition levels and n_b is the decomposition level corresponding to the subband b (see Fig.2). Note that $N_L = n_b$ in the LL subband, and there are two parameters, N_L and n_b in Eq.(2) because quantization step sizes depend on subbands in JPEG 2000. In JPEG 2000, the quantization step size Δb is represented by

$$\Delta_b = 2^{R_b - \varepsilon_b} \times (1 + \frac{\mu_b}{2^{11}}). \quad (3)$$

where

$$R_b = \begin{cases} R_I, & \text{(LL)} \\ R_I + 1, & \text{(LH, HL)} \\ R_I + 2, & \text{(HH)} \end{cases} \quad (4)$$

$$\varepsilon_b = \varepsilon_0 - N_L - n_b, \quad (5)$$

$$\mu_b = \mu_0, \quad (6)$$

where R_I is the bit-depth of the tile component. ε_0 and μ_0 are a mantissa value and an exponent one of the Δ_b for the LL subband respectively. As shown in Eqs.(3)-(6), the Δb is scaled by power of two depending on N_L and n_b. The formula shown in Eq.(2) is based on the this scale.

B. In the case of no quantization of DWT coefficients

When DWT coefficients are not quantized , namely all quantization step sizes are always $\Delta b = 1$, the formula for calculating approximate DWT coefficients is simple. We do not need to consider the relationship among subbands. Therefore, to estimate approximate DWT coefficients, the following formula is given as

$$W_i = 2^{-N_{zbp}}. \quad (7)$$

IV. EXPERIMENTAL RESULTS

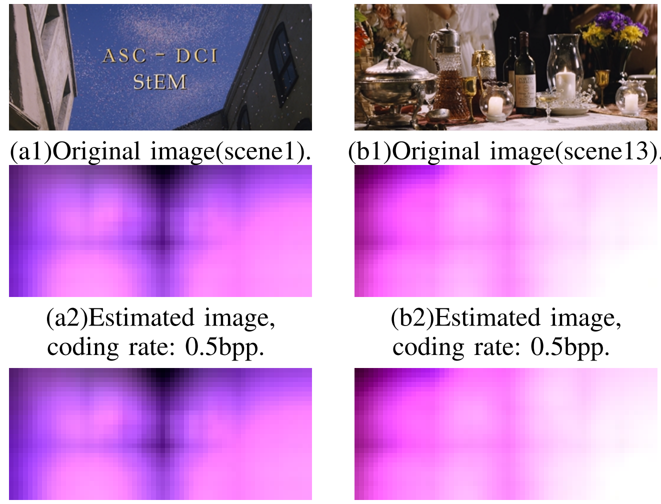
The Standard Evaluation Material (StEM) [14] was used as a material of the test set. The StEM consists of 17239 video frames with the resolution of 4096×1714, which are provided as 48-bit TIFF files. 500 frames which consisted of 20 frames per scene were selected from the StEM as the test set. That is, there are 25 scenes in the set. Kakadu version 6.4 [15] was used as the JPEG 2000 codec.

A. Image estimation

Estimation results obtained by the proposed method are given in Fig.6. From these results, we can see that estimated images: 1) do not have enough visible imformation on orignal images, 2) remain nearly unaffected by compression bit rates, and 3) have some information on the difference among scenes. The property 2) is given due to the robustness of the NZBP to changing coding rates shown in Sec.II. As a result, it is shown that images estimated by the information for header parts are useful for image identification.

B. Signature values

Next, image signature values, which are utilized in MPEG 7 for image retrieval or image identification, are calculated as an image similarity index for estimated images or images decoded by JPEG 2000. The triple feature as an image signature is calculated by the trace transform[13], where three transformations, namely, trace functional, diametric functional, circus functional, are performed on images. We can choose any functionals from that given in ref[13] for each transformations. We show the functionals which are used in Table I. The trace functional maps an image to another two dimensional space. The diametric functional reduce the dimension by applying it along vertical axis in the mapped 2-d space. Similarly, the circus functional was applied along horizontal axis. Fig.7 (a) and (b) show triple feature values of estimated images and decoded ones respectively. The values of estimated images remain nearly unaffected by compression bit rates.

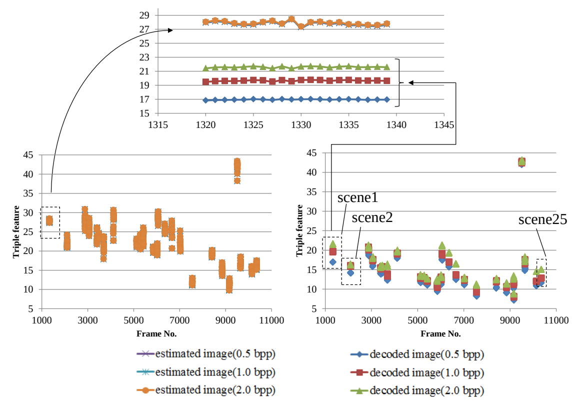


(a1)Original image(scene1). (b1)Original image(scene13).

(a2)Estimated image, coding rate: 0.5bpp. (b2)Estimated image, coding rate: 0.5bpp.

(a3)Estimated image, coding rate: 1.0bpp. (b3)Estimated image, coding rate: 1.0bpp.

Fig. 6. Original images and estimated images(Code-block size: 64 × 64, DWT Level: 5).



(a) Estimated images. (b) Decoded images.

Fig. 7. Triple feature values (Code-blocks size: 64× 64, DWT decomposition level: 5).

C. Image identification

Image identification was carried out by using triple feature values. Each database consisted of 500 triple feature values

TABLE I. THE SET OF THREE TRANSFORMS FOR THE TRACE TRANSFORM.

Trace functional	$\int \lvert f(t)' \rvert dt$
Diametric functional	$\int f(t) dt$
Circus functional	$\int f(t) dt$

TABLE II. IDENTIFICATION RESULTS(ESTIMATED IMAGES).

$SR(C_x, C_y)$ [%]		C_x [bpp] (Query)		
		0.5	1.0	2.0
C_y[bpp] (Database)	0.5	100.0	97.2	79.8
	1.0	97.8	100.0	88.8
	2.0	78.6	87.0	100.0

(a) $k = 5$.

$SR(C_x, C_y)$ [%]		C_x [bpp] (Query)		
		0.5	1.0	2.0
C_y[bpp] (Database)	0.5	100.0	100.0	98.8
	1.0	100.0	100.0	99.8
	2.0	98.4	100.0	100.0

(b) $k = 10$.

TABLE III. IDENTIFICATION RESULTS(JPEG 2000 IMAGES).

$SR(C_x, C_y)$[%]		C_x [bpp] (Query)		
		0.5	1.0	2.0
C_y [bpp] (Database)	0.5	100.0	2.0	2.0
	1.0	2.0	100.0	2.0
	2.0	2.0	2.0	100.0

(a) $k = 5$.

$SR(C_x, C_y)$[%]		C_x [bpp] (Query)		
		0.5	1.0	2.0
C_y [bpp] (Database)	0.5	100.0	4.0	4.0
	1.0	4.0	100.0	4.8
	2.0	4.0	4.0	100.0

(b) $k = 10$.

calculated from JPEG 2000 codestreams with a coding rate. A query value was chosen from the databases. The following criterion was used for image identification.

$$W(C_x, C_y, n) = \arg \underset{m}{\text{k-min}} \{|T_e(C_y, m) - T_e(C_x, n)|\}, \quad (8)$$

where

$$\begin{cases} n, m \in \{1, 2, \cdots, 500\}, \\ C_x, C_y \in \{0.5, 1.0, 2.0[\text{bpp}]\}, \end{cases} \quad (9)$$

where $T_e(C_, n)$ is the triple feature value of an estimated image under a coding rate C_x. "k-min$\{\cdot\}$" represents that extracting the values which are from the minimum to kth-smallest after the minimum. A query $T_e(C_x, n)$ is one of values in the database $T_e(C_y, m)$. According to Eq.(9), Eq.(8) is carried out $500 \times 500 = 250000$ times in total for each combination of C_y and C_x. The success or failure for the query $T_e(C_x, n)$ is determined by the following rules:

$$\begin{cases} \text{success} & (n \in W(C_x, C_y, n)), \\ \text{failure} & (n \notin W(C_x, C_y, n)). \end{cases}$$

For each combination of C_y and C_x, the success rate $SR(C_x, C_y)$ is given by

$$SR(C_x, C_y) = \frac{\text{the number of successful queries}}{500} \times 100. \quad (10)$$

As shown in Table II, estimated images are robust against the changing of coding rates, and the proposed method is useful for the image identification. In the same way, instead of estimated images triple feature values of decoded images $T_d(C_, n)$ were used for the image id entification. The results for decoded images are shown in Table III. Decoded images are unsuitable for this application.

D. Consideration on security

We confirmed that it is difficult to obtain the visual information of original images from estimated images. However, we could identify estimated images to images in the databases with high probability. This means that it is possible to do image identification without using body data. These experimental results show that header parts have some important information of original images even if the content of estimated images are not perceivable. As mentioned above, the information is extracted from header parts. Because of this, it is necessary that JPEG 2000 codestreams should be protected not only body data but also header parts to ensure full confidentiality and minimize the information leakage.

V. CONCLUSION

We proposed an image estimation method by using header information in JPEG 2000 codestreams. Some information was directly extracted from header parts, and was used to estimate an original image without using any body data. The relationship between estimated images and original ones were considered with the object of both image identification in the compressed domain and secure image communications, by using the signature values. The values of estimated images remain nearly unaffected by compression bit rates. Estimated images are robust against the changing of coding rates, and the proposed method is useful for the image identification. As a results, it is necessary that JPEG 2000 codestreams should be protected not only body data but also header parts to ensure full confidentiality and minimize the information leakage.

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