Lossless JPEG2000 Coding for Lossy Images and its Applications

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ABSTRACT

We consider lossy image coding methods using integer wavelet transforms and describe new applications of lossless JPEG2000 coding for re-encoding without the use of any coding parameters, such as the target rate. The relationship between lossless and lossy coding based on JPEG2000 is discussed and an efficient lossless coding method for lossy images is proposed. The proposed method is useful for the dubbing and editing of images and video sequences. By providing the result of some simulations, we demonstrate the effectiveness of the proposed method.

1 INTRODUCTION

Lossless image coding can compress images without introducing any distortion. In general, the images for lossless coding are original images, which have not been encoded by any lossy image coding method. If images with some coding distortion, referred to as lossy images, are applied to lossless coding, the coding rate of the lossless coding is much more than that of lossy coding [1,2]. Therefore, most lossless coding methods are not designed to handle lossy images. In this paper, the relationship between lossless and lossy coding methods is discussed, and an efficient lossless coding method for lossy images is proposed.

Images are often encoded repeatedly, for example, in editing, dubbing, and transcoding operations. Lossy coding methods are used in these operations plurally. However, deterioration of the image quality is unavoidable, even if the target rate of the second lossy coding is the same as that of the first lossy coding [3]. Moreover, to keep the amount of deterioration introduced low, we need to use a lot of coding parameters in the first encoding when re-encoding a lossy image [4–6].

In this paper, we propose using lossless JPEG2000 [7] coding to re-encode lossy images. The proposed method does not require the use of any coding parameters except for wavelet filter coefficients, and the lossless coding rate of the re-encoding can be close to the target rate of the first lossy coding. The conditions of the first lossy coding are considered, so that the applications of JPEG2000 using lossless wavelet transforms and of the post-quantization in the EBCOT [8] algorithm are shown as the conditions. As a result, the proposed method can be applied to some applications of JPEG2000 and Motion JPEG2000 [9].

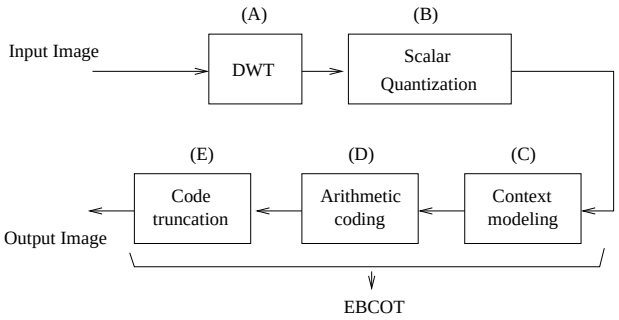

Figure 1: A block diagram of JPEG2000 encoder

In the following sections, we describe JPEG2000 coding, and discuss the re-encoding process and its problems. Then, an efficient re-encoding method eliminates the problems is proposed. To verify the effectiveness of the proposed method, we perform simulations of its compression performance.

2 OVERVIEW OF JPEG2000 CODING

In this section, we review JPEG2000 coding. JPEG2000 coding is a kind of unified lossless/lossy coding. The differences between lossless and lossy algorithms are two parts. The first part is in the implementation of discrete wavelet transform (DWT), and the second part is in the rate-control scheme.

Fig. 1 shows the coding procedure of the JPEG2000 encoder. The JPEG2000 encoder consists of roughly five parts described as follows.

(A) DWT

DWT is carried out by the mallat decomposition of 2-channel filter banks in JPEG2000. Filters in the filter banks are classified into two types: One is an integer filter that has integer coefficients, and the other is a floating filter that has non-integer coefficients. Lossless JPEG2000 coding uses integer DWT (IWT) that is carried out by lifting schemes with integer filter and round operation. On the other hand, lifting schemes having floating filters or lifting schemes of integer

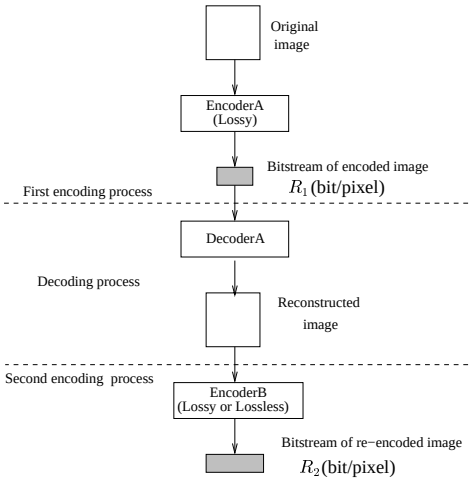

Figure 2: A re-encoding process

filters without round operation, that which we call floating DWT (FWT) in this paper, is used in the lossy coding. It is noted that IWT can be used in lossy coding although it is a lossless transform.

(B) Scalar quantization

In JPEG2000 coding, the use of two rate-control methods is allowed. One is code truncation in the EBCOT algorithm called post-quantization, and the other is pre-quantization using a scalar quantizer. Either the post-quantization or the pre-quantization method can be used in lossy coding.

Meanwhile, no rate-control operation is required for the lossless coding.

(C)(D)(E) EBCOT algorithm

EBCOT is one of the bit-plane based coding algorithms. The transformed coefficients are decomposed into bitplanes and are encoded by the MQ arithmetic coder. Then, these encoded coefficients are truncated for the rate-control. When IWT is used as DWT and pre-quantization is skipped, there is no difference between lossy coding and lossless coding until the code truncation is performed.

To perform lossless coding, we have to choose IWT and skip both the pre-quantization and the post-quantization steps.

3 RE-ENCODING AND PROPOSED METHOD

We define a re-encoding process discussed in this paper and describe its problems. Then, we explain the idea to eliminate the problems and propose an efficient lossless coding method for lossy images.

3.1 Re-encoding process

A re-coding process is shown in Fig.2. This is roughly divided into three processes described as follows.

• *First encoding process*

In the first encoding process, an original image is encoded at a target rate R_1(bit/pixel) by the lossy encoder A. Then the bitstream of encoded image is transmitted to the decoding process.

• *Decoding process*

The bitstream is decoded at the decoder A and the reconstructed image is generated as a lossy image.

• *Second encoding process*

In this process, the reconstructed image is re-encoded by the encoder B. The encoder B can be either lossless or lossy encoder. Finally, the bitstream of the re-encoded image is generated where its coding rate is R_2(bit/pixel).

These three steps are often carried out in applications of editing such as scene changing of images or video sequences, dubbing, or transcoding.

3.2 Problems of re-encoding

The quality of the re-encoded image or the coding rate R_2 in Fig. 2 is depend on the encoder B. The aim of this paper is to propose a re-encoding process where the re-encoding image has the rate $R_2 \simeq R_1$ and the same image quality as that of the first encoding.

A. Case of lossy re-encoding

When a lossy encoder is chosen as the encoder B, it is not difficult to obtain the rate $R_2 \simeq R1$. However, in general, the quality of the re-encoded image deteriorates compared to that of the reconstructed image in the decoding process. This deterioration is unavoidable even if we use the coding parameters the same as those of the first encoding process.

B. Case of lossless re-encoding

When a lossless encoder is chosen as the encoder B, it is not difficult to keep the image quality without the use of the coding parameters in the first encoding process. However, the coding rate R_2 becomes quite larger than R_1 ($R_2 \gg R_1$) in general.

Although the proposed method is in the case B, it can achieve $R_2 \simeq R_1$. In the following, we consider the conditions to avoid the increase of the coding rate R_2 and propose an application of lossless JPEG2000 coding for lossy images.

3.3 Proposed method

Here, we propose a re-encoding process using JPEG2000. Fig.3 shows the procedure of the proposed re-encoding process, where the encoders A, B and the decoder A are based on JPEG2000. As the default, lossy JPEG2000 coding employs FWT and lossless JPEG2000 coding employs IWT. Note that IWT is also available for lossy JPEG2000 coding.

As mentioned before, the use of lossy encoders causes the quality deterioration of images in the second coding process. To avoid this, in the proposed process, the lossy JPEG2000

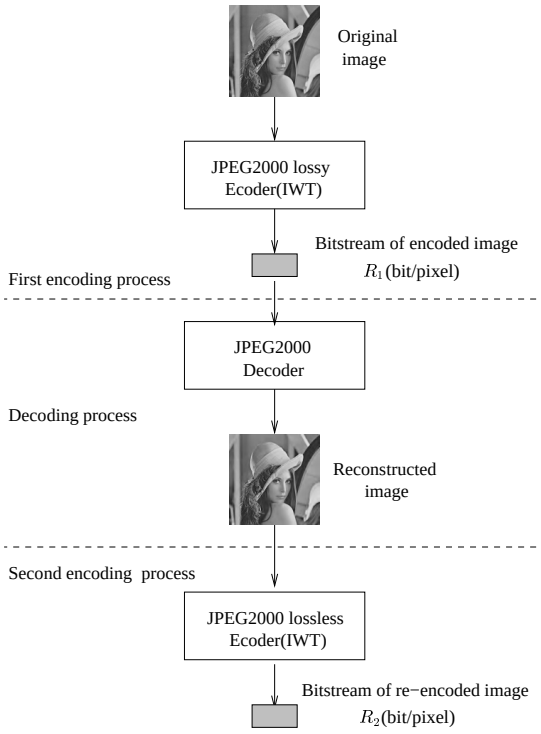

Figure 3: Procedure of the proposed re-encoding

coding with the use of IWT is employed as the first encoding and the lossless JPEG2000 is used as the second process. Moreover in the proposed process, some conditions between the first and the second encoding process are considered as follows.

A. Lossy encoder for the first encoding process
A-1. Condition on DWT
In the first encoding process, the lossy JPEG2000 encoder is employed to achieve the target rate R_1, where an IWT has to be used as the DWT. This condition is derived from considering the matching between the first and the second process, described later.

A-2. Condition on the rate-control operation
The rate-control operation is done by using only post-quantization in the first encoding process. If pre-quantization is used in this process, the context modeling in the first encoding process differs from that in the second encoding process. In the proposed process, we use the lossless JPEG2000 coding for the second encoding, so that pre-quantization is never used in the first encoding process to take the matching of the rate-control operation.

B. Lossless encoder for the second encoding process
To take the matching of the transforms, IWT used in the second encoding process has to be the same as that of the first encoding process. In other words, the wavelet filter coefficients should be identical among the re-encoding processes.

The conditions are summarized as table1, where 'SQ' means the use of scalar quantizers for the rate-control and 'TRUNC' means the use of the code truncation for the rate-control in the EBCOT.

Table 1: The conditions between the fist and the second encoding process.

First encoding			Second encoding		
DWT type	SQ	TRUNC	DWT type	SQ	TRUNC
IWT	skipped	used	IWT (the same as the first)	skipped	skipped

4 SIMULATIONS

4.1 Simulation condition

To confirm the effectiveness of the proposed method, we provide some simulations on the compression performance. In the simulations, two test images called 'lena'(512x512, 8bit/pixel) and 'barbara'(704x480, 8bit/pixel) are used. We use JPEG2000 VM8.6(verification model version 8.6) codec for the simulations.

We compared the four types of re-encoding in the simulations, as shown in table 2. 'Proposed' is the proposed re-encoding method. 'Mismatched' are the re-encoding which has mismatch of the wavelet transform used between lossy and lossless encoders. The second column stands for the DWT type used in the lossy JPEG2000 encoders, and the third column stands for that used in lossless JPEG2000 encoders. For lossless encoders, the lifting implemented CDF5x3 [13] filter is used since it is the default of the lossless JPEG2000. We compare the proposed re-encoding with the mismatched re-encoding in the sense of lossless coding rate. D9x7 in table2 means the Doubechies 9x7 filter [13] which is adopted as the default FWT filter for the lossy JPEG2000. MIT9x7 [14] in the table is one of IWT.

We use the EBCOT algorithm for both lossless and lossy JPEG2000 for the rate-control. In other words, We do not use any scalar quantization to control the coding rate.

4.2 Evaluation of simulation results

Figs.4 and 5 show the results of simulations. Horizontal axis stands for the target rate of first encoding process. Vertical axis stands for the coding rate of re-encoding process. In these figures, 'Lossy coding rate' is equal to the target rate at first encoding process. A curve which passes close the

Table 2: Conditions on the transform used in JPEG2000 encoders for the simulations.

-	Lossy JPEG2000	Lossless JPEG2000
Proposed	IWT(CDF5x3)	IWT(CDF5x3)
Mismatched I	FWT(D9x7)	IWT(CDF5x3)
Mismatched II	FWT(CDF5x3)	IWT(CDF5x3)
Mismatched III	IWT(MIT9x7)	IWT(CDF5x3)

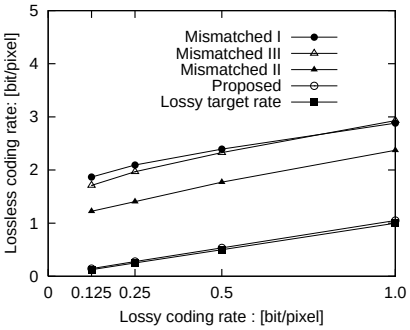

Figure 4: Coding results of re-encoding in image 'Lena'.

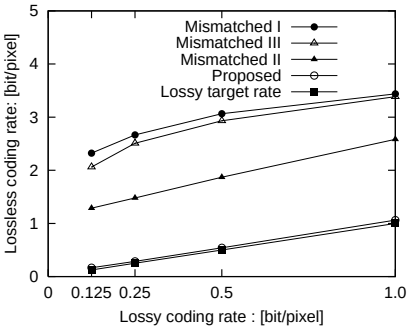

Figure 5: Coding results of re-encoding in image 'Barbara'.

curve of 'Lossy coding rate' is considered as the better performance.

From Figs.4 and 5, the results of 'Proposed' give the best performance compared to those of 'Mismatched I', 'Mismatched II' and 'Mismatched III'.

From the evaluation of the simulation results, it is shown that lossless coding is useful for encoding lossy images under some conditions. It is noted again that no parameters except for the filter coefficients are necessary in the proposed method. The effectiveness of the proposed method is based on the embedded property of JPEG2000.

5 CONCLUSIONS

We have considered the condition for the efficient re-encoding. We showed that these conditions are on DWT and the rate-control operation which are used in the encoders in the re-encoding process. The proposed re-encoding process performs the lossless coding for the lossy images without the use of any coding parameters employed in the lossy coding.

To verify the efficiency of the proposed method, we provided the re-encoding simulations based on JPEG2000 standard.

The proposed method is not limited to the use in the JPEG2000 standard. As future-works, we will investigate the application of the proposed re-encoding process for the other image coding standards.

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