Lossless Transform with Functionality of Thumbnail Previewing

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***Abstract*— This report proposes a new functionality of lossless coding of image signals. The proposed method provides 'thumbnail previewing' of the original image from a part of the bit-stream without expanding all the compressed data. It also avoids degradation of resolution in pixel density of the thumbnail image. It is composed of a new lossless color transform and an existing lossless wavelet transform. We add a free parameter to the color transform and utilize it to control a scaling parameter of the luminance component. As a result, it became possible to preview the 'thumb-nail' luminance image from a part of the bit-stream. Due to the free parameter, quality and data volume of the 'thumbnail' can be controlled according to a users' request. Unlike the existing two layer lossless / lossy coding, the proposed method achieves good performance in lossless coding of the original image signal.**

I. INTRODUCTION

Due to the international standardization of image data compression algorithms such JPEG, numerous applications have been developed for digital storage and communication of image signals [1]. Most of them are composed of the 'lossy' coding to attain high compression ratio. Since their decoded images contain quantization errors, the 'lossless' coding algorithms have been also developed for digital archiving, medical image analysis [2], etc.

Since most of the 'lossy' coding and 'lossless' coding are based on different signal processing modules, integration of those two algorithms has been discussed from various points of view [3-5]. In this report, we discuss on constructing a new 'lossless' coding considering backward compatibility with the conventional 'lossy' coding.

The JPEG 2000 provides each of the lossy coding and the lossless coding. The former is based on the irreversible color transform (Irr.CT) and the 9/7 discrete wavelet transform (DWT). The latter is based on the reversible color transform (Rev.CT) and the 5/3 integer DWT [1]. The 9/7 DWT has its integer version which can be utilized for lossless coding [6,7]. However, The Rev.CT is not such counterpart of the Irr.CT in JPEG 2000.

An integer color transform (Int.CT) compatible with the Irr.CT in JPEG 2000 has been proposed in [8]. It is composed of three lifting steps [6]. Adding one more lifting step, another type of the Int.CT have been proposed in [9,10]. In these reports, the Int.CT were investigates from various points of view, such as rounding errors due to short word length expression of signals and coefficients, bit depth increase inside the transform, etc. It was extended to KLT and its singular point problem was discussed in [11,12]. However, coefficients of the Int.CT in these previous reports have been fixed according to a given condition.

In this report, unlike those previous Int.CTs, we add a free parameter to the four lifting step Int.CT, and utilize it to control image quality of a 'thumbnail' image. In the proposed method, a luminance image as the 'thumbnail' can be decoded from a part of the bit-stream. Due to this functionality, it becomes possible to preview the original image without expanding all the compressed data. Quality and data volume of the 'thumb-nail' image can be also controlled with the free parameter according to a users' request.

II. EXISTING METHOD

A. Problem Setting

Fig.1 illustrates the situation we are going to discuss. Data volume of the original image $\boldsymbol{A}$ is compressed with the new 'lossless' encoder. It is decoded without any loss from both of the bit streams (compressed data) '$\boldsymbol{Bs}_1$' and '$\boldsymbol{Bs}_2$'. It has functionality that a conventional 'lossy' decoder can be applied to those bit streams to decode an approximation $\boldsymbol{A}^*$ of the original image $\boldsymbol{A}$.

In this report, we add the functionality that a 'thumbnail' image $\boldsymbol{B}$ can be also decoded from the bit stream '$\boldsymbol{Bs}_1$', under the constraint that the images $\boldsymbol{A}$ and $\boldsymbol{B}$ have the same number of pixels. Due to this new functionality, it becomes possible to preview the original image without expanding all the compressed data and degradation of spatial resolution.

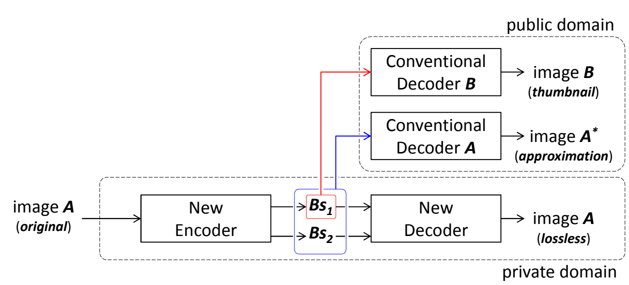


Fig.1 Purpose of this report.

B. Existing Approach

Fig.2 illustrates an existing approach. A conventional ‘lossy’ transform such as the 9/7 DWT is applied to the original image ***A***. Its output ***C*** is processed with an entropy encoder such as the EBCOT to generate the bit stream $\boldsymbol{Bs}_1$. Another bit stream $\boldsymbol{Bs}_2$ contains difference between the original image ***A*** and the decoded image ***B***. This subtraction based two layer approach is commonly utilized for lossless / lossy image coding [13].

In this case, the thumbnail image ***B*** can be decoded without degradation of resolution in pixel density. However, it is ‘redundant’ in respect of total number of pixels, since both of ***C*** and ***D*** have the same number of pixels. As a result, the total number of pixels becomes double comparing to ***A***.

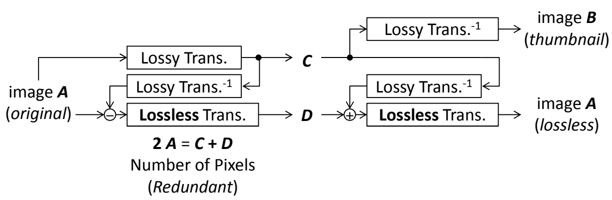


Fig.2 The existing method.

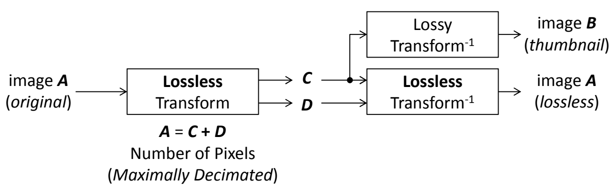


Fig.3 The proposed method at a glance.

III. Proposed Method

A. Concept of the Proposed Method

Fig.3 illustrates a rough sketch of the proposed method. Unlike the existing approach, the proposed method is not redundant, namely ***A***=***C***+***D*** in number of pixels. It contributes to achieve good performance in lossless coding of the original image ***A***. Fig.4 illustrates the proposed method in detail. The lossless transform is composed of the ‘Lossless Color Transform’ and the ‘Lossless DWT’. The latter is the integer version [6] of the 9/7 ‘Lossy DWT’ defined by JPEG 2000 for lossy coding [1]. Originality of this report exists in the former ‘Lossless Color Transform’.

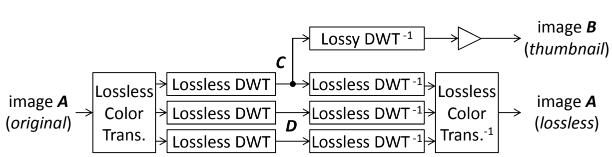


Fig.4 The proposed method in detail.

B. Proposed Lossless Color Transform

Fig.5 illustrates the proposed lossless color transform. Similarly to the previous works in [9,10], it is composed of four lifting steps $\mathbf{L}_1$, $\mathbf{L}_2$, $\mathbf{L}_3$ and $\mathbf{L}_4$. The permutation **P** is carefully selected from its variations so that the system becomes robust to the rounding errors [11,12]. It also contains the scaling **S**. This part is not used in the lossless coding mode.

Multiplier coefficients $\{a,b,c,d,\cdots k\}$ are determined so that this color transform becomes exactly the same as a given color transform $\mathbf{A}_0$ in the conventional decoder ***A*** in Fig.1. Note that some of the coefficients can be zero as stated in [12]. However, we utilize this redundancy as the freedom of controlling quality of the thumbnail image ***B*** in Fig.4.

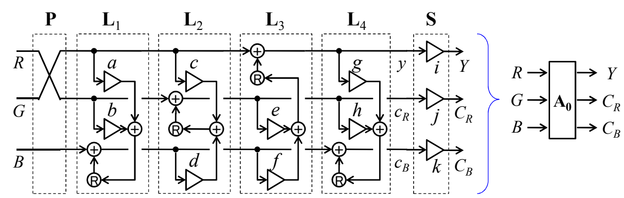


Fig.5 Design of the proposed lossless color transform.

C. Proposed Thumbnail Previewing System

Fig.6 illustrates implementation of the proposed system. In the ‘lossless coding’, the lifting $\mathbf{L}_p$, $p \in \{1,2,3,4\}$ and the permutation **P** are applied to color components $\{R, G, B\}$ of the original image ***A***. Each of the color components $\{y, c_R, c_B\}$ are fed into the lossless DWT and then entropy coded. Unlike the existing method, total data volume of ***C*** and ***D*** (= $\boldsymbol{D}_1$+$\boldsymbol{D}_2$) can be maintained under acceptable level as indicated in the next section.

In the ‘previewing’, this is the originality of this report, only the data ***C*** is decoded with a conventional ‘Lossy DWT’. Its pixel values are multiplied with the coefficient i in the scaling **S**, to produce the ‘thumbnail’ image ***B***. This coefficient i is the free parameter in our proposal to control quality and data volume of the thumbnail as indicated in the next section.

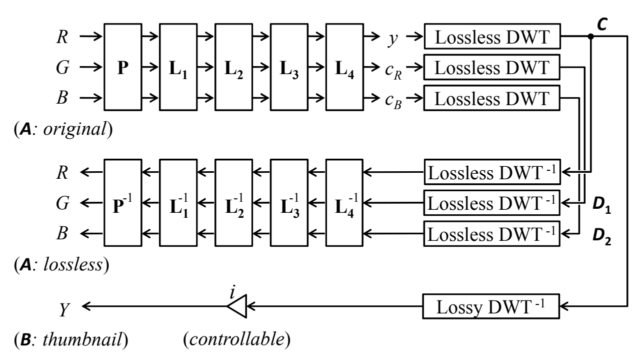


Fig.6 Implementation of the proposed system.

D. Determination of the Coefficients

For a given lossy color transform $\mathbf{A}_0$ in the 'conventional decoder $\boldsymbol{A}$' in Fig.1 (or a 'lossy transform' in Fig.3), the coefficients $\{a,b,c,d,\cdots k\}$ are determined as below.

$$k=|\mathbf{A}|/(ij), \quad d=U/j, \quad b=(T-j)/U \tag{1}$$

$$\begin{bmatrix} g \\ h \end{bmatrix}=\begin{bmatrix} R/i & U/j \\ Q/i & T/j \end{bmatrix}^{-1}\cdot\begin{bmatrix} X/k-1 \\ W/k-b \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} a \\ c \end{bmatrix}=\begin{bmatrix} -P/i & -S/j \\ UP/(ij) & US/j^2 \end{bmatrix}\begin{bmatrix} g \\ h \end{bmatrix}+\begin{bmatrix} V/k \\ S/j-UV/(jk) \end{bmatrix} \tag{3}$$

$$\begin{bmatrix} f \\ e \end{bmatrix}=\left[\begin{bmatrix} Q/i & T/j \\ R/i & U/j \end{bmatrix}\begin{bmatrix} g \\ h \end{bmatrix}-\begin{bmatrix} W/k & -T/j \\ X/k & -U/j \end{bmatrix}\right]^{-1}\cdot\begin{bmatrix} -Q/i \\ -R/i \end{bmatrix} \tag{4}$$

for

$$\mathbf{A}=\begin{bmatrix} P & Q & R \\ S & T & U \\ V & W & X \end{bmatrix}=\mathbf{A}_0\cdot\mathbf{P}^{-1}. \tag{5}$$

In this form, two of the coefficients are redundant. For example, setting [g h]=[0 0] results in the three lifting step Int.CT in [8]. In this report, we set h=0 to obtain one free parameter i. Substituting (1) into (2), we have

$$\begin{bmatrix} g \\ h \end{bmatrix}=\frac{1}{M_{31}}\left(\frac{ij}{|\mathbf{A}|}\begin{bmatrix} +iM_{11} \\ -jM_{21} \end{bmatrix}+\frac{j}{U}\begin{bmatrix} 0 \\ M_{31}+Rj \end{bmatrix}\right). \tag{6}$$

Setting h=0 in (6), we have

$$j=\frac{M_{31}|\mathbf{A}|}{iM_{21}U-R|\mathbf{A}|} \tag{7}$$

for

$$M_{11}=\begin{vmatrix} T & U \\ W & X \end{vmatrix}, \quad M_{21}=\begin{vmatrix} Q & R \\ W & X \end{vmatrix}, \quad M_{31}=\begin{vmatrix} Q & R \\ T & U \end{vmatrix}. \tag{8}$$

Consequently, all the coefficients are determined according to the free parameter i.

E. Other Functionality

As stated in the subsection II.A, a conventional 'lossy' decoder can be applied to $\boldsymbol{C}$, $\boldsymbol{D}_1$ and $\boldsymbol{D}_2$ as illustrated in Fig.7 to decode the approximation $\boldsymbol{A}^*$ of the original image $\boldsymbol{A}$. In this lossless / lossy 'transcoding coding', the scaling $\mathbf{S}$ is applied as stated in [14].

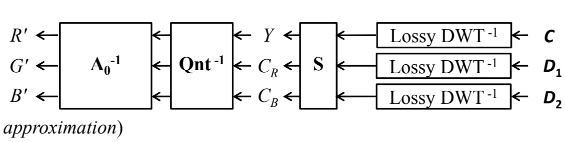


Fig.7 Lossless / lossy transcoding mode

IV. Experiments

Fig.8 summarizes the coefficients determined form the free parameter i for the lossy color transform defined as

$$\mathbf{A}_0=\begin{bmatrix} .2999 & .5870 & .1140 \\ .5 & -.4187 & -.0813 \\ -.1687 & -.3313 & .5 \end{bmatrix} \tag{9}$$

in JPEG 2000. The proposed transform can include each of the previous Int.CTs [8-10] as a special case. In any case, our transform is exactly the same as the given $\mathbf{A}_0$ when the errors due to the rounding operations ® in Fig.5 are negligible.

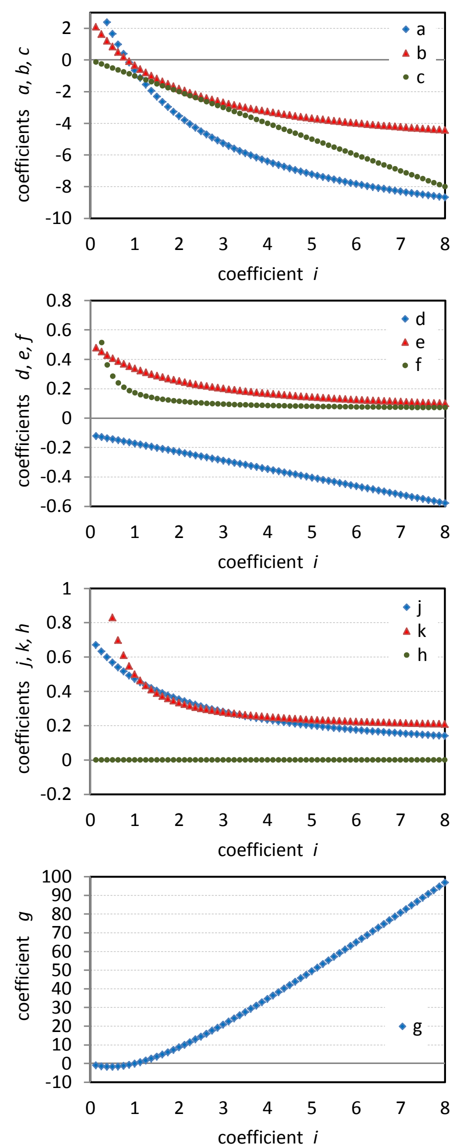
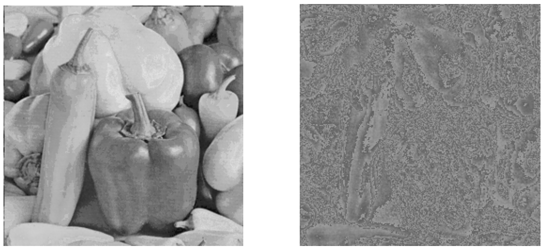


Fig.8 Coefficients determined from i.



(a) Decoded thumbnail (b) Errors $\times 4 + 128$

Fig.9 Thumbnail image and its errors for i=16.

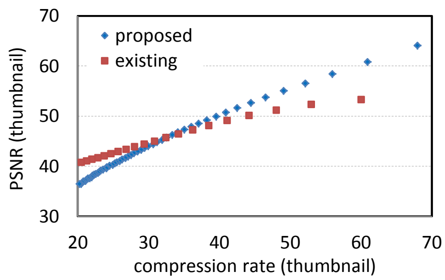


Fig.10 Quality and data volume of the thumbnail image.

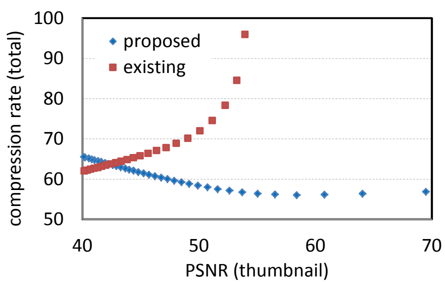


Fig.11 Image quality and lossless compression ratio in total.

An example of the thumbnail image and its errors are indicated in Fig.9 for i=16 of the proposed method. Image quality and data volume of the thumbnail Y in Fig.6 can be controlled with the free parameter i. It was confirmed from the rate distortion curve illustrated in Fig.10, where image quality is evaluated with the peak signal to noise ratio (PSNR). The compression ratio in the figure is defined as the ratio of data volume after compression and before.

Fig.11 indicates total data volume of $\boldsymbol{C}$ and $\boldsymbol{D}$ (= $\boldsymbol{D}_1$+$\boldsymbol{D}_2$) in lossless coding mode for the existing method in Fig.2 and the proposed method in Fig.3. It indicates that the existing method can't reach the compression rate of less than 60 [%] for the PSNR of over 40 [dB]. Moreover, the ratio becomes more than 95 [%] in the worst case. On the contrary, the proposed method maintains the ratio between 57 and 65 [%].

V. Conclusions

A free parameter was introduced in the four lifting integer color transform, and it was utilized for previewing a thumbnail image. Its quality and data volume were controlled according to a user's request, under the constraint that pixel density of the thumbnail image is the same as the original image. Since the thumbnail image is limited to monochrome, it should be extended to color in the near future.

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