A Lossy Image Coding Method Based on Histogram Packing

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***Abstract*—This paper proposes a lossy image compression method. The proposed method once increases the sparseness of the histogram, and then it packs the histogram before lossless compression. Experimental results show the effectiveness of the proposed method.**

I. Introduction

JPEG-2000 [1], [2] is the latest international standard for still image compression. It was designed mainly with the aim of compressing continuous-tone images. However there are images with sparse histograms. Compressing these images by the codecs like JPEG-2000 is difficult. To overcome this, the image preprocessing technique referred to as *histogram packing* [3] has been proposed.

Histogram packing rearranges the sparse histograms of images. The rearranged images can be compressed losslessly with higher efficiency by the codecs like JPEG-2000. For lossy compression, however, histogram packing degrades the peak signal-to-noise ratio (PSNR) except the nearly lossless range [4].

In this paper, that lossy image compression with the histogram packing is investigated and considered, and then the problems like the degrading of PSNR are pointed out. Finally, a new lossy image compression method with the histogram packng that solves the problems is proposed. The proposed method introduces a sparsification process and compresses images losslessly. This method improves PSNRs for high bitrate encoding. In addition, the compressed image quality can be selected. Experimental results show the effectiveness of the proposed method.

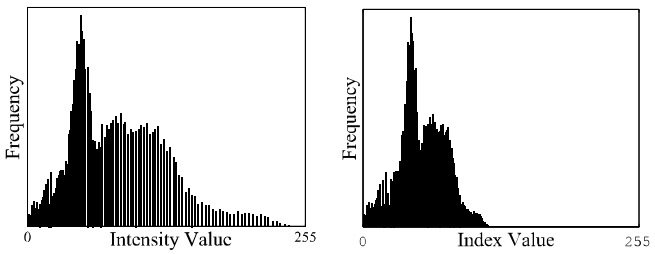
II. Preliminaries

This section describes the images with sparse histograms, followed by the image preprocessing technique referred to as *histogram packing* [3] that is the base of the proposed method.

A. Images with sparse histograms

If a N bpp image does not use the complete set of 2^N available intensity values, and the used intensity values are sparsely spread all over the $[0 \sim 2^N - 1]$, then the histogram of such image contains gaps between nonzero bins, i.e., the histogram is sparse, as shown in Fig. 1 (a).

The image preprocessing technique for this kind of images is discribed in the next section.



(a) Sparse histogram. (b) Packed histogram.

Fig. 1. An example of histograms.

B. Histogram packing

Histogram packing [3] is the image preprocessing technique that maps intensity values to index values to clear all gaps away in the (sparse) histogram of an input image. Fig. 1 shows the example of histogram before packing (a) and the one after packing (b).

To be more precise, let us assume that $I_0, I_1, ..., I_{n-1}$ denote the n different intensity values that are used in an input image. In other words, they have nonzero bins in an input image histogram. Then the histogram packing is defined by

$$I_0 \mapsto 0, I_1 \mapsto 1, ..., I_{n-1} \mapsto n-1$$

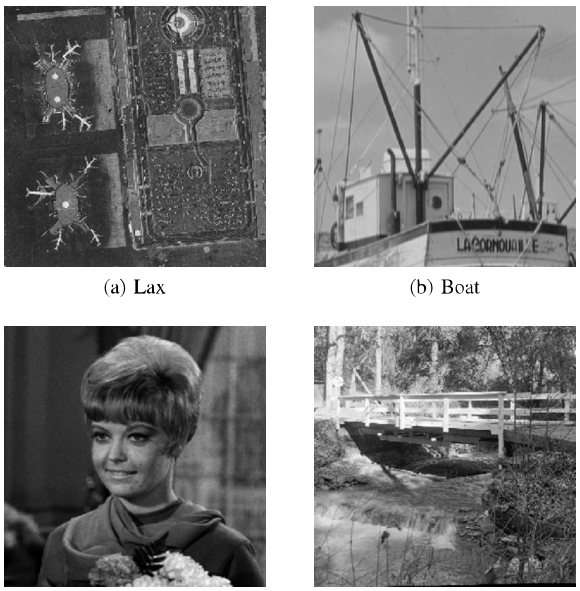
which maps ascending sorted intensity values into ascending sorted contiguous index values where intensity-index values relations are stored in a look up table(LUT) for later recovery of the original intensity values.

The intensity values of each adjacent pixels become closer by packing, so the packed image is losslessly compressed with higher efficiency by the codecs like JPEG-2000 [4]. Thus, the sparser the histogram of an input image is, the higher the lossless compression efficiency of the packed image is.

However in the lossy compression case, the packing gives the negative effect described in the next section.

III. Lossy Compression Method with Histogram Packing

As previously described, the packed image is losslessly compressed with higher efficiency. In this section, we investigate and consider the lossy compression case.



(a) Lax (b) Boat

(c) Girl (d) Bridge

Fig. 4. 256×256-sized 8 bpp gray scale images for evaluations.

TABLE I
CONDITIONS.

Input images format	8 bpp gray scale
Input images size	256×256 [pixels]
Compression and decompression	JPEG 2000 codec with 5×3 filter

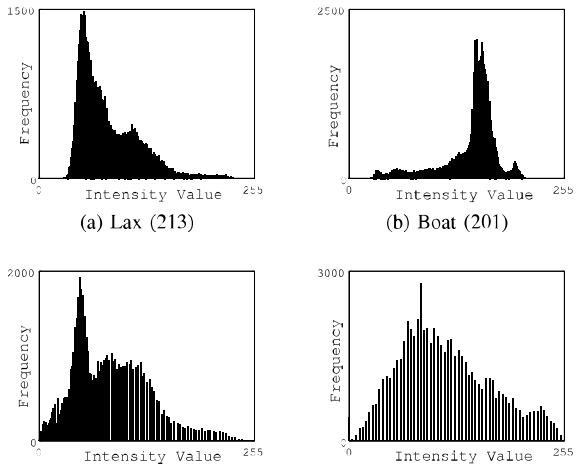
A. Investigation

Fig. 2 shows the encoding processes of simple lossy compression method(simple method) and lossy compression method with histogram packing(packing method). Fig. 3 shows the decoding ones.

To investigate the packing method, these two methods were evaluated with various *Compression Rate*s. In this evaluation, four of 256×256-sized 8 bpp gray scale input images are used as shown in Fig. 4, and JPEG 2000 codec with 5×3 filter was used for the compression and decompression. The input images' histograms and the number of used intensity values are also shown in Fig. 5. Conditions are summarized in Table. I. Derived PSNRs between the input images and the decoded images with each *Compression Rate*s are shown in Fig. 6.

As shown in Fig. 6 (a) and (b), it is found that the packing makes almost no impact on compression efficiency when the input image's histogram has little sparseness.

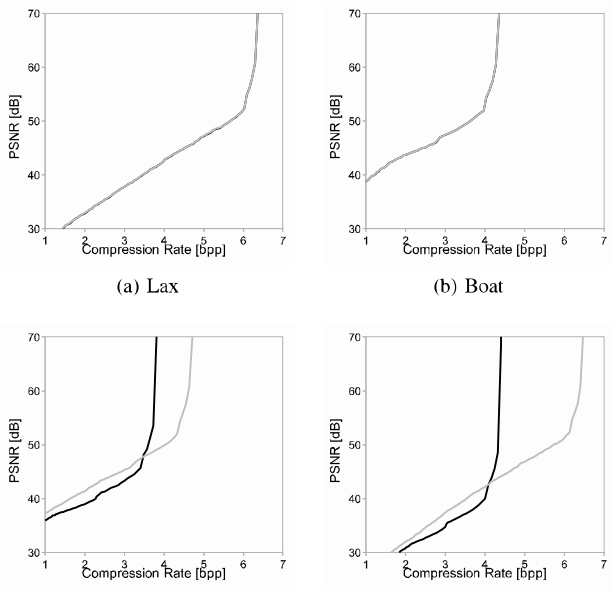
And from Fig. 6 (c) and (d), the packing method improved the compression efficiency in the nearly lossless range. But the packing method's PSNRs are drastically decreasing according to the compression rate decreasing. This is caused by the index value errors produced by the lossy compression after the packing. An index value error introduces huge distortion through inversely mapped to different pixel value with the LUT at the unpacking in the decoding process.



(a) Lax (213) (b) Boat (201)

(c) Girl (120) (d) Bridge (64)

Fig. 5. Input images' histograms and the number of used intensity values.



(a) Lax (b) Boat

(c) Girl (d) Bridge

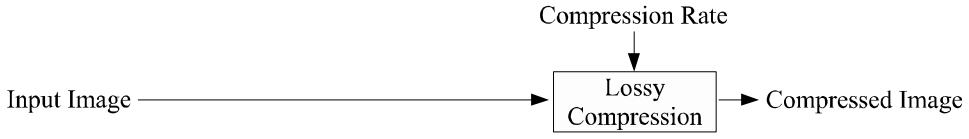
Fig. 6. Rate-distortion curves of simple method(gray) versus packing method(black).

B. Problems

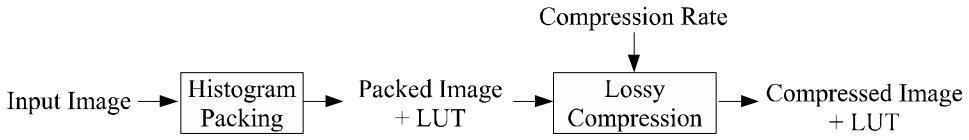
This section summarizes the problems of the packing method as follows.

- Only the images with sparse histograms are improved.
- PSNRs are degraded by the index value errors.

In the next section, a new lossy image compression method with the histogram packng that solves these problems is proposed. The proposed method can also select the quality of the compressed image.

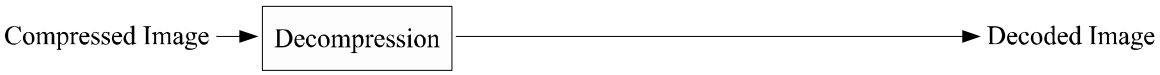


(a) Simple lossy compression method.

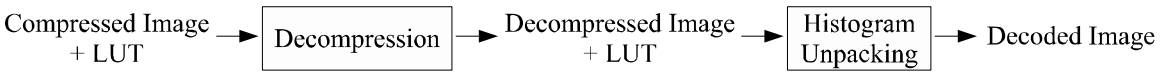


(b) Lossy compression method with histogram packing.

Fig. 2. Block diagrams of the encoding processes.



(a) Simple lossy compression method.



(b) Lossy compression method with histogram packing.

Fig. 3. Block diagrams of the decoding processes.

IV. Proposed method

This section proposes a new lossy image compression method with the histogram packng that solves the problems in Sect. III-B and can select the quality of the compressed image. The proposed method once increases the sparseness of the histogram, and then it packs the histogram before lossless compression.

In the packing method, there is the lossy processing after packing, which improves the compression rate at the expense of the compressed image quality. As a result of that, huge intensity value errors are produced. So, we focused on performing that lossy processing before the packing. The lossy processing before the packing is implemented as the *histogram sparsification* in Fig 7 (a). Fig 7 shows the encoding and decoding process of the proposed method.

A. Histogram sparsification

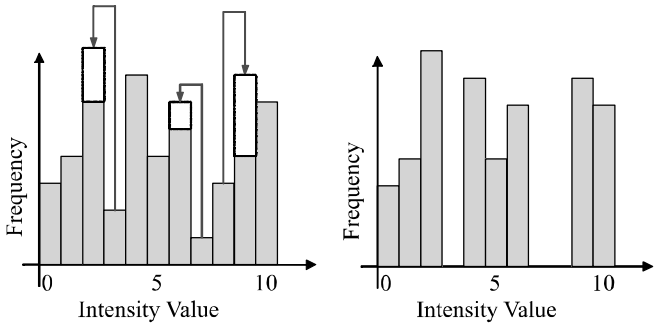
The histogram sparsification increases the sparseness of the histogram by mapping intensity values to another as long as the processed image satisfies a *Desired PSNR* as shown in Fig. 8. It means that we can select the processed image quality. Because the sparser the input image histogram is, the better compression efficiency is improved. So the lossy processing before packing that improves the compression rate at the expense of the compressed image quality is archived.

B. Features

Now, there is no lossy processing after the packing, thus the proposed method prevents the degradation of PSNRs mentioned in the Sect. III-B. And histogram sparsification can be applied to not only the images with sparse histograms but also the images with little sparse histograms. So the features of the proposed method can be summerized as follows:

- It doesn't matter whether the input images' histograms are sparse or not.
- No index value errors are produced.
- The quality of the compressed image can be selected.

To confirm these features, experimental results are presented in the next section.



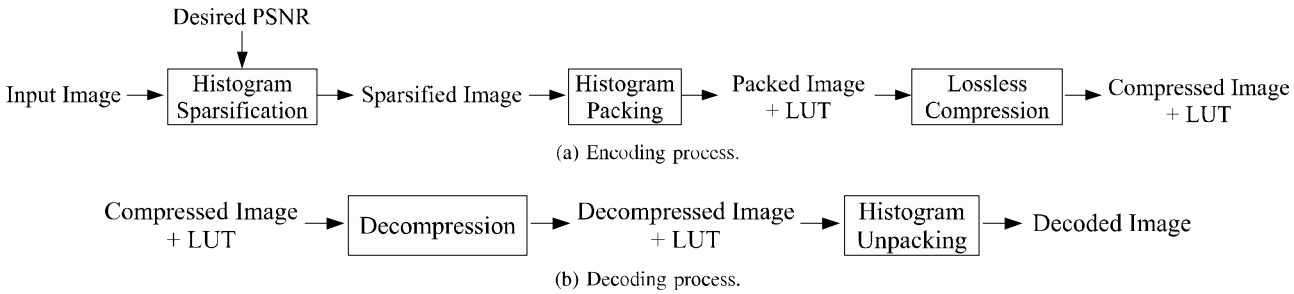
(a) Histogram being sparsified. (b) Sparsified histogram.

Fig. 8. Histogram sparsification.

V. Experimental Results

The proposed method were evaluated with various *Desired PSNR*s. Conditions are same as Table. I.

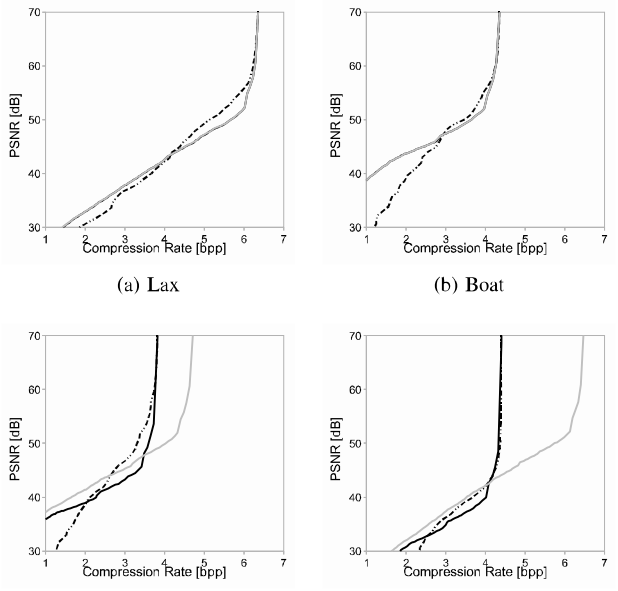
Fig. 9 shows the Fig. 6 overwritten with the derived curve of the proposed method. From Fig. 9, it is found that the proposed method gives betther PSNRs than the other above 2 or 3 bpp and is also valid in the images with little sparse histograms. The effectiveness of the proposed method is confirmed.



(a) Encoding process.

(b) Decoding process.

Fig. 7. Block diagrams of the proposed method.



(a) Lax (b) Boat

(c) Girl (d) Bridge

Fig. 9. Rate-distortion curves overwritten with the derived curve of the proposed method(dot).

VI. Conclusions

This paper has proposed the lossy image coding method based on histogram packing. Experimental results show the effectiveness of the prposed method.

References

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[3] A.J. Pinho, "An online preprocessing technique for improving the lossless compression of images with sparse histograms," *IEEE Signal Process. Lett.*, vol.9, pp.5–7, Jan. 2002.

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