Image Zooming for Indexed Color Images Based on Bilinear Interpolation

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Abstract

In this paper, a novel image zooming scheme for indexed color images is proposed. In the proposed scheme, the bilinear interpolation technique is employed to enlarge the original image. Then, the pixel grouping process is executed to classify the pixels in the enlarged image. From the experimental results, it is shown that the proposed scheme provides better image quality than the pixel copy technique for the zooming of the indexed color images.

Keywords: *image zooming, color image quantization, color palette, bilinear interpolation*

1. Introduction

Among the common image processing operations, image zooming [1]-[10] is a basic function of digital image processing. It can be used to adjust the size of the digital image and it is commonly applied to multimedia applications, such as digital camera, image database, electronic publishing, and medical imaging. In general, the original image to be enlarged is often called the low-resolution image and the enlarged image is called the high-resolution image. From the literature, the image zooming schemes can be classified into two approaches: fixed image zooming [1]-[3] and adaptive image zooming [4]-[10].

Till now, some fixed image zooming techniques, such as the pixel copy technique [1], the bilinear interpolation technique [2], and the bi-cubic interpolation technique [3], had been proposed. The pixel copy technique is the simplest technique for image zooming. The unknown pixels in the enlarged image are recovered by its corresponding sampled pixels in the original image of the pixel copy technique. The major drawback of this technique is that the blocking effect can be easily found in the pixel copy technique when the scaling factor is high. Besides, the image quality of the enlarged image by using the pixel copy technique is poor. The bilinear interpolation technique is a popularly used technique for image zooming. It works well for the smooth areas zooming, but the blocking artifact can be found in the edge boundaries of the enlarged image when the bilinear interpolation technique is used.

Currently, some adaptive image zooming techniques, such as the edge preserving zooming technique [4, 5, 8, 9], the local adaptive zooming technique [6], the vector quantization zooming technique [7,10], had been proposed. The goal of edge preserving zooming techniques is to remove/reduce blocking artifacts occurring in image interpolation. In other words, they can preserve more clear edge boundaries in the enlarged image than the fixed image zooming techniques. However, the image quality of the enlarged image by using the edge preserving zooming technique is not always better than that of the fixed image zooming technique.

The local adaptive zooming technique [6] was proposed by Battiato et al. in 2002. In this technique, the gradient-controlled and weighted interpolation is executed. It speeds up the entire adaptive process without requiring a preliminary gradient computation. In 2005, Chang et al. proposed the vector quantization zooming technique [7]. The unknown pixels in the enlarged image are interpolated by using a vector quantization codebook based on their local information in this technique. In addition, the improved image zooming based on bilinear interpolation and the vector quantization scheme [10] were proposed in 2011.

From the literature concerning the image zooming techniques, most of them work on the color or grayscale images in raw format. However, the zooming of the color indexed images is also important because the color indexed images that were compressed by the color image quantization (CIQ) technique [11]-[17] are commonly used for multimedia. Basically, the CIQ scheme can be divided into three procedures: palette design, image encoding and image decoding. In the image encoding procedure, the closest color in the color palette for each color pixel is searched. The index of the closest color in the color palette is recorded. The compressed codes of CIQ for the RGB color image consist of the index table and the color palette.

The image zooming techniques already published for color images in raw format can be directly applied to the image zooming of the indexed color image. However, the image quality of the enlarged indexed color image is not good enough. In this paper, we aim to design a good image zooming scheme for indexed color images. The remaining of this paper is organized as follows. In Section 2, the proposed image zooming scheme for indexed color images will be introduced. The experimental results will listed in Section 3. Finally, the conclusions will be given in Section 4.

2. The Proposed Scheme

Given the indexed color image of $w \times h$ pixels, the indexed color image consist of $w \times h$ indices, and the color palette *CP* consists of *N* colors. The scaling factor *SF* is set to 2 in the proposed scheme. The enlarged indexed color image *E* of $W \times H$ pixels is to be generated where $W = w \times 2$ and $H = h \times 2$. The flowchart of the proposed scheme is depicted in Fig. 1.

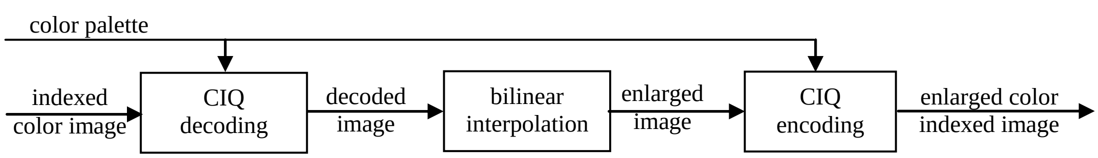


Figure 1. Flowchart of the Proposed Scheme

Firstly, the indexed color image is first decoded to generate the decoded image *DI* of $w \times h$ pixels in raw format. The image decoding procedure of CIQ can be done by recovering each color pixel by the color in *CP* corresponding to its index. Then, the bilinear interpolation technique is employed to enlarge *DI*. After the bilinear interpolation technique is executed, the enlarged image *EI* of $W \times H$ pixels is generated.

Then, the enlarged image *EI* and the color palette *CP* of *N* colors are used to generate the refined color palette. The closest color in *CP* for each pixel in *EI* is searched. The enlarged image *EI* is compressed by CIQ with the use of the refined color palette to generate the enlarged indexed color image *E* of $W \times H$ pixels. The closest color in the refined color palette is determined and the corresponding index is recorded. By successively compressing each pixel in *EI* by the same way, the resultant indexed color image *E* is thus generated.

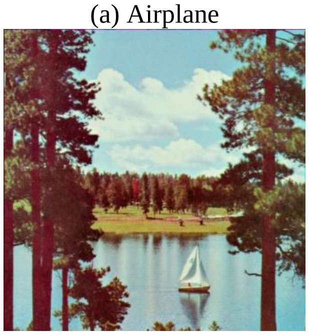
3. Experimental Results

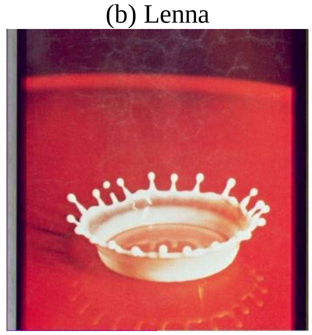
The simulations are executed on Microsoft windows XP with an Intel Core Duo 2.2GHz CPU and 512Mbytes RAM. The codes are implemented by using Bloodshed Dev C++. In the simulations, six color images of 512×512 pixels "Airplane", "Lenn "Pepper", "Sailboat", "Splash" and "Toys" as shown in Fig. 2 are used as the testing images for performance comparison. In the simulations, each 512×512 color image in raw format is sub-sampled to generate the 256×256 low-resolution image in raw format. Then, each 256×256 low-resolution image is compressed by the color image quantization technique to generate the low-resolution color indexed image. Each 256×256 indexed color image is enlarged to generate the 512×512 high-resolution indexed color image. In other words, the scaling factor *SF* is set to 2 in the simulations.

(a) Airplane


(b) Lenna


(c) Pepper


(d) Sailboat


(e) Splash

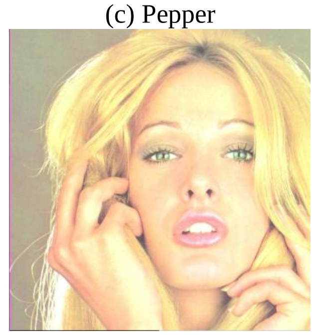

(f) Tiffany

Figure 2. Six Testing Images for Performance Evaluation

The similarity between the original image and the enlarged image is compared. To measure the image quality of the compressed image, the Mean Square Error (*MSE*) between the piexels of the original image and those of the enlarged image is defined as

$$MSE = \frac{1}{W \times H} \sum_{i=1}^{W} \sum_{j=1}^{H} (o_{ij} - e_{ij})^2. \quad (1)$$

Here, o_{ij} and e_{ij} denote the color pixels in the original color image in raw format and those in the high-resolution color indexed image, respectively. The quality of the high-resolution color indexed image is measured by means of the peak signal-to-noise-ratio (*PSNR*), which is defined as

$$PSNR = 10 \times \log_{10} \frac{255^2}{MSE}. \quad (2)$$

Basically, *PSNR* is considered as an indication of image quality rather than a definitive measurement; however, it is a commonly used measurement for evaluating the image quality.

Experimental results of the image qualities by the color image quantization technique for 256×256 images are listed in Table 1. The image quality increases in the color image quantization technique with the increase of the palette size. Average image qualities of 28.182 dB, 32.790 dB and 37.276 dB are achieved by using the pixel copy technique when the palette sizes are 16, 64 and 256, respectively.

Table 1. Image Qualities of the Color Image Quantization Technique for 256×256 Images

Images	N = 16	N = 32	N = 64	N = 128	N = 256
Airplane	30.143	32.724	36.043	38.160	40.335
Lenna	28.649	30.965	33.485	35.420	37.305
Pepper	25.737	27.700	30.008	32.788	34.864
Sailboat	26.757	28.646	30.393	32.461	34.528
Splash	28.863	31.483	33.781	36.631	39.043
Tiffany	28.944	30.930	33.028	35.421	37.583
Average	**28.182**	**30.408**	**32.790**	**35.147**	**37.276**

Image qualities of the enlarged 512×512 RGB images by using the pixel copy technique with CIQ are listed in Table 2. In addition, image qualities of the enlarged 512×512 RGB images by using the proposed scheme are listed in Table 3. From the results, it is shown that the proposed technique provides better image qualities than the pixel copy technique with CIQ do. Average image qualities of 27.087 dB, 28.575 dB and 29.330 dB are achieved by using the bilinear interpolation technique when the palette sizes are 16, 64 and 256, respectively.

Table 2. Image Qualities of the Enlarged 512×512 RGB Color Images by the Pixel Copy Technique

Images	N = 16	N = 32	N = 64	N = 128	N = 256
Airplane	24.891	25.393	25.498	26.618	26.678
Lenna	25.615	26.477	27.132	27.406	27.606
Pepper	23.551	24.455	25.116	25.348	25.596
Sailboat	22.549	23.074	23.325	23.464	23.533
Splash	25.598	26.619	27.191	27.633	27.830
Tiffany	24.827	25.394	25.782	26.073	26.220
Average	**24.505**	**25.235**	**25.674**	**26.090**	**26.244**

Table 3. Image Qualities of the Enlarged 512×512 RGB Color Images by using the Proposed Scheme

Images	N = 16	N = 32	N = 64	N = 128	N = 256
Airplane	27.564	28.383	28.836	29.037	29.163
Lenna	27.970	29.433	30.589	31.164	31.556
Pepper	25.580	27.008	28.128	28.854	29.311
Sailboat	27.513	25.963	26.434	26.795	26.998
Splash	27.513	28.919	29.785	30.465	30.777
Tiffany	26.381	27.155	27.677	28.041	28.175
Average	**27.087**	**27.810**	**28.575**	**29.059**	**29.330**

Some enlarged 512×512 images of these comparative methods for the testing images "Lenna" and "Tiffany" are listed in Figs. 3 and 4, respectively. In Fig. 3, the reconstructed image qualities of the pixel copy technique with CIQ and the proposed scheme are greater than 30 dB. From the results, the visual qualities of these enlarged images in Fig. 4 are quite good. The image qualities of the reconstructed images as shown in Fig. 4 are less than 30 dB. Their visual qualities are slightly worse than those in Fig. 3.

(a) Pixel copy + CIQ,
PSNR = 27.606 dB

(b) Proposed Scheme,
PSNR = 31.080 dB

Figure 3. Some Enlarged 512×512 images of "Lenna"

(a) Pixel copy + CIQ,
PSNR = 26.220 dB

(b) Proposed Scheme,
PSNR = 27.765 dB

Figure 4. Some Enlarged 512×512 images of "Tiffany".

4. Conclusions

A novel image zooming scheme for indexed color images is introduced in this paper. The indexed color images are compressed by the color quantization scheme to cut down the storage cost of the RGB color images. To improve the image qualities of the enlarged indexed color images is a great challenge because of the limitation of the color palette. From the results, it is shown that the proposed scheme outperforms the pixel copy technique for the zooming of indexed color images.

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