A Novel Picture Coding Using Colorization Technique

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Abstract
Colorization is a computerized process of adding color to a black and white print, movie and TV program. The authors have proposed automatic colorization algorithms by giving a partial color to a monochrome image. This paper focuses on the colorization process which can produce a color image from a monochrome image with a small number of color pixels, and proposes a novel color image coding algorithm based on the colorization technique. At first, luminance component is separated from an input color image. Next, selected color seeds from the original color image are sown on the luminance image domain automatically and the monochrome image is colorized. The sowing process is continued until the colorized image satisfies the desired quality. Finally, both orthogonal transform-coded luminance component and the set of color seeds are transmitted as coded data. The decoding can be performed by tracing the same colorization process. We confirmed that the colorization technique is effective to image coding through the experiments.

Introduction
With the recent spread of the internet and multimedia technologies, digital images play more and more important role in human visual communications. In order to reduce image data quantity, several image compression algorithms have been developed. Most of them, such as JPEG2000, make use of the spatial correlation. In natural images, a strong correlation can also be observed among tri-color signals. The authors have focused on luminance-chrominance redundancies, and have been proposed novel images compression algorithms.[1,2] This paper stands on the extension of those works, but uses a different approach.

In this century, the study of "colorization" begins to attract attention. Colorization is a technology of coloring monochrome images automatically by giving a few hints of color. Welsh et al. proposed a semi-automatic algorithm by transferring color from a reference color image.[3] Levin et al. proposed an interactive colorization method by giving some color scribbles.[4] The authors have also proposed a few colorization algorithms by sowing color pixels.[5-9] This paper presents basic experimental results for applying a colorization technique to image data compression.

Figure 1 shows the overview of the proposed coding scheme. At first, luminance component is separated from an input color image. Next, selected color seeds from the original color image are sown on the luminance image domain automatically and the monochrome image is colorized. The sowing process is continued until the colorized image satisfies the desired quality. Finally, both orthogonal transform-coded luminance component and the set of color seeds are transmitted as coded data. In the colorization process, our pixel-sowing colorization techniques[5-9] have an advantage than other techniques. Because it is difficult to extract color hint by using other colorization techniques such as reference images and color scribbles. Furthermore, the proposed technique meets the human visual system well in which the sensitivity of the eye to luminance detail is higher than that of chrominance detail. The detailed algorithm will be explained in the following sections.

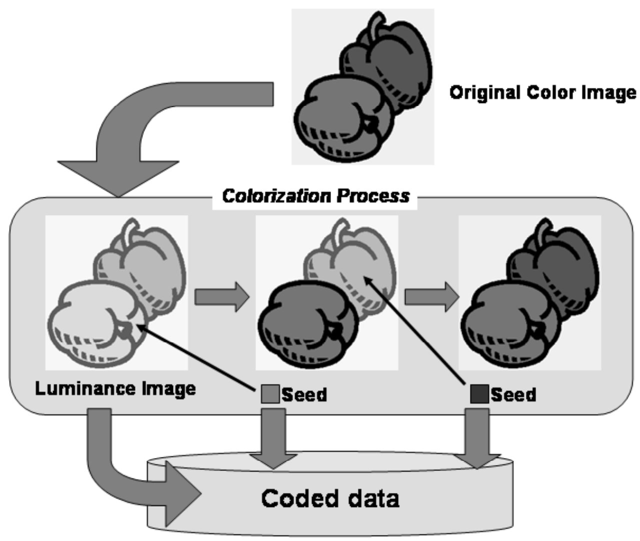

Figure 1. The proposed coding model using colorization technique.

(a) Monochrome image. (b) Colorized image.

Figure 2. Colorized result by Ref. [8].

Colorization Algorithm
In the proposed coding algorithm, all techniques in Refs. [6] through [9] can be used as the colorization process. In this paper, we briefly introduce a colorization technique in Ref. [8].

Let $I = (x, y)$ be a pixel in an input monochrome image and let S be a set of color seeds. The color seeds, which are color pixels strictly, are given as a prior knowledge by the user. Therefore, position and coloring of those seeds are determined by the user. Note that the color must be chosen with keeping the luminance of the original monochrome pixels. Since we present our method in

CIELAB color space, each monochrome pixel I is transformed into the luminance signal $L(I)$. Note that other color space like YCC, YUV would work equally well. The color seed S is also transformed into a luminance component and a pair of chrominance components $L(S)$,$a(S)$,$b(S)$, respectively.

In Ref. [8], a four-connected pixel I of the seed S is colorized by $L(I)$,$a(S)$,$b(S)$ components in CIELAB color space, if the following partitioning condition satisfies:

$$\left|L(I)-L(S)\right|<Th. \tag{1}$$

where Th means a threshold of the partition. The partition works for preventing error propagation. If the difference of luminance between adjacent pixels is larger than the threshold, the color propagation stops. Otherwise, the color propagation will be continued to the next adjacent pixels. When the propagation stops everywhere, a next color seed is sown on the remaining monochrome pixels. The sowing process will be continued until all pixels will be colorized.

Figure 2 shows an example of colorization by using the algorithm in Ref. [8]. Figure 2(a) shows an input monochrome image with red circles which expresses the position of color seeds. Each seeds were sown at the center of the circle. In this example, seven seeds were finally sown on the monochrome image for colorizing all monochrome pixels. Figure 2(b) shows the colorized result.

Image Coding Algorithm

This section shows the proposed image coding algorithm, which consists of luminance component decomposition, color seed selection, color propagation and data coding.

Decomposition of the Luminance Component

First of all, luminance component is separated from an input color image. In this paper, we would explain the colorization process in CIELAB color space, the color image transfers into $L^*a^*b^*$ planes here using the popular color transformation.

Color Seeds Selection

As explained in the previous section, in the colorization algorithm in Ref. [8], the position and color of seed pixels were given by the user. However, in the image coding process, it is required to select them automatically. Fortunately, the color of seeds can be determined by the input color image. Therefore, we should extract only the position of seeds automatically. Here we tested the following three methods for placing of seeds.

Random

Obviously, a random setting of seeds resulted in the worst and huge seeds were required to colorize all pixels, because it is independent of image color distribution and seeds were sown on isolated regions. It is required to propagate many pixels by each color seed for reducing data size.

Selection From High Luminance Histogram

This method assumes that pixels in the same region have almost the same luminance. According to the assumption, a pixel with the luminance of high histogram may belong to a large region on the image. Seeds will be selected depending on the present luminance histogram.

Box Center at Higher Pixel Density in CIELAB Space

To select more reliable seeds depending on the input image, we generated $M=m^3$ pieces of rectangular boxes in CIELAB color space surrounded by the regular lattice points inside the min-max color ranges of image color distribution.

The image color distribution is partitioned by a unit box with the size of $\Delta a \times \Delta b \times \Delta L$

$$\begin{aligned}\Delta L &= [\max\{L_n^*\}-\min\{L_n^*\}]/m \\ \Delta a &= [\max\{a_n^*\}-\min\{a_n^*\}]/m \\ \Delta b &= [\max\{b_n^*\}-\min\{b_n^*\}]/m\end{aligned} \tag{2}$$

Let a color vector be $\boldsymbol{X}_n$ for n-th data point and $\boldsymbol{\mu}$ for the mean vector in CIELAB.

$$\boldsymbol{X_n} = [L_n^*, a_n^*, b_n^*]^t \;; n=1\sim N \tag{3}$$

$$\boldsymbol{\mu} = E\{\boldsymbol{X}\} = [\overline{L}^*, \overline{a}^*, \overline{b}^*]^t \tag{4}$$

Here, we count up the pixel population $P(k)$ existing inside the each box $\boldsymbol{b}_k$; $k=1\sim M$. Next, a body center with the highest color population is selected as the position of a seed. This method requires a calculation time, but accurate color seed can be selected depending on the color distribution of the input image.

Color Propagation

Color propagation is realized by the colorization technique in the previous section. However, in the actual image, there are huge isolated regions in which connected component is less than a few pixels. In the case of Fig. 3, 47% of all pixels are isolated regions in which connected component is less than four pixels by setting a threshold. Actually, more than half pixels are required for colorizing the image, and it occurs to the data explosion. To avoid the problem, colorization does not performed if the region consists of less than four pixels. After all pixels are colorized except for isolated regions, we adopt a collapsing algorithm for constructing partition.

Collapsing Algorithm

As decreasing the threshold Th of partition in Eq. (1), the colorization is performed forcibly for isolated regions.

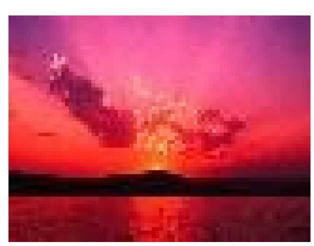

Figure 3. A color image with many isolated regions.

(a) Original color image.
(900 Kbyte)

(b) Luminance component.
(19.9 Kbyte)

(c) Restored image by the proposed method.
(20.0 Kbyte, 28.1[dB])

(d) JPEG image.
(34.4 Kbyte, 25.6[dB])

(e) JPEG image. (19.8 Kbyte, 22.1[dB])

Figure 4. Experimental results for "Backingham".

(a) Original color image.
(900 Kbyte)

(b) Luminance component.
(22.5Kbyte)

(c) Restored image by the proposed method.
(22.9 Kbyte, 24.7[dB])

(d) JPEG image.
(29.5 Kbyte, 24.9[dB])

(e) JPEG image. (22.2 Kbyte, 22.7[dB])

Figure 5. Experimental results for "Scottsdale".

Data Coding

From the above process, the input color image becomes luminance components and the small number of seed pixels. According to the human visual perception, the luminance components must be coded precisely. In our algorithm, the luminance components will be coded by an orthogonal transform coding, such as wavelet and DCT with high quality. The data of each seed pixel can be coded as four dimensional vector, that is coordinate (x,y) and chrominance components (a^*,b^*). If 2 Byte will be assigned for each component, it takes 8 Byte for each color seed.

Decoding Algorithm

The decoding process can be performed by tracing the colorization process in the coding algorithm. Therefore, it can calculate speedy. The monochrome data is restored and each monochrome color seeds are sown on the monochrome image. Then the reproduced image can be obtained by continuing the propagation of color seeds.

Experimental Results

In order to verify the performance of the proposed method, we compared the proposed coding method with JPEG using natural images. Figure 4 shows an example of experimental results. The data quantity of the original image is 900 Kbyte (640×480 pixels). The decomposed monochrome image was coded by JPEG and the data quantity became 19.9 Kbyte. The number of color seeds was seven. Therefore, the data quantity was 0.05 Kbyte. In totally, the data quantity was about 20 Kbyte and the compression ratio was 0.02. We verified the image quality by PSNR. The PSNR between Fig. 4(a) and Fig. 4(c) was 28.1[dB].

In order to compare with present JPEG color coding, we produced a JPEG image with almost the same PSNR (28.1[dB]) as the Fig. 4(c) by tuning the image quality parameter. Figure 4(d) shows the restored result. The PSNR was 25.6 [dB], but the data quantity was 34.4 Kbyte which is larger than Fig. 4(c). On the other hand, we produced another JPEG image with almost the same data quantity (20.0 Kbyte) by tuning the parameter. Figure 4(e) shows the restored image by JPEG. The data quantity was 19.8 Kbyte, but the PSNR was 22.1 [dB] which is lower than Fig. 4(c). Obviously, the image deteriorated as shown in Fig. 4(e). Therefore, the coding ability of the proposed method is higher than JPEG on this image.

Figure 5 shows other test image "Scottsdale". In this image, 50 seeds were needed for coding the image. The effectiveness of the proposed method can also be verified.

In both images, most of the data quantity is occupied by the monochrome component. This property shows that the monochrome coding is very important in the proposed colorization coding. In our experiment, we used JPEG coding for luminance component. As decreasing the quality, the colorized results were improved, because the number of isolated region was also decreased. However, if the quality decreases too much, the colorized results becomes worth and worth. We have to try to use other orthogonal transforms and investigate more suitable coding method for luminance component.

Conclusion

This paper proposed a novel color image coding method using colorization technique. Experimental result showed that the proposed technique has the possibility that can obtain more effective result than present image coding technique.

Acknowledgment

Part of this work has been supported by the Tateisi Science and Technology Foundation in Kyoto, Japan.

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Author Biography

Megumi Nishi received her B.E. degree from Chiba University, Japan in 2004. Since 2004, she has been a graduate student in the Master's Program in Science and Technology of the same university. Her current research interest is image coding based on vision model.