For Colorization using Template Matching Basic Research on

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Abstract*: Colorization, also known as colorization, is a term introduced by Wilson Markle in 1970, and is a method of coloring black-and-white images and videos using a computer. Coloring is important. Imagine coloring a picture as an example. The painting before painting only gives information of existence, such as trees, flowers, and clouds. Some things can be identified by color. This does not give us enough information from the picture. But what about coloring? If you paint the sky red, it will be a sunset, and if you paint the ground green, it will be a meadow. In other words, it is possible to express not only the background but also the background. This makes it possible to read information that cannot be understood only in black and white. With the development of digital devices such as smartphones these days, the chances of seeing black-and-white images are decreasing, but in modern times, black-and-white images are used for X-ray images, MRI images, aerial photographs, fixed-point observations, etc. There are many opportunities to be lost. The development of color photography began in the world in the 1800s, and the development of color photography began in Japan in 1940. In other words, the photographs before that were black and white, and colorization was used to colorize them. Currently, many researchers are studying colorization methods and processes, and the processing time and the burden on users are being reduced. However, software that can perform highly complete colorization is expensive, and some are complicated to operate. Therefore, in this research, as basic research for the development of a fully automatic colorization program for free software, color images (template images) lacking information by template matching using ZNCC and black-and-white images with similar brightness patterns are colored. We made a prototype of a colorization program that restores images.

Keywords: Computer graphics, Colorization, Zero-means Normalized Cross-Correlation, BMP image, HSV color space, Color Propagation

I. INTRODUCTION

The term colorization is a term introduced by Wilson Markle in 1970 [1]. This term refers to a computer-assisted process for colorizing black and white images. Coloring is important. Imagine coloring a picture as an example. The picture before painting has only information about the existence of trees, flowers, and clouds. But what about coloring? If you paint the sky red, you get a sunset, and if you paint the ground green, you get a meadow. That is, it is possible to express not only the existence but also the background. This makes it possible to read information that cannot be understood only in black and white. With the recent development of digital devices such as smartphones, the chances of seeing black-and-white images have decreased, but even today, there are many opportunities to use X-ray images, MRI images, aerial photographs, and fixed-point observations. The development of color photography began in the 1800s, but the first color photography was developed in Japan in 1940. In other words, the pictures before that are black and white. Colorization is used to colorize these images. There are also examples of black-and-white movies being colored for the first time in the early 20th century [1]. Currently, many researchers are conducting research on colorization methods and processes, and the processing time and the burden on users are being reduced. However, software that can perform highly complete colorization is expensive, and some software is complicated to operate. Therefore, in this study, as a basic study for developing a fully automatic coloration program of free software, a color image is restored from a black-and-white image having a brightness pattern similar to a color image lacking information by template matching using ZNCC. We made a prototype of the coloration program.

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II. COLORING METHOD

There are roughly two methods for coloring a black and white image. One is to read an image and color it automatically, and the other is to specify the color and place to be colored by the user to some extent and then color it. This study was conducted on the former. The program in this paper needs to prepare a "template image" in addition to a black and white image. The template image is an image for performing template matching. The program in this paper uses two images, a black and white image and a template image, to generate a colored image. A black and white image and a template image are used as input data, and a colored image is used as output data. The general flow of coloring is template matching between a black-and-white image and a template image, transferring the color, and then propagating the color to an unpainted part.

III. BMP IMAGE AND HSV COLOR SPACE

The program created in this study handles only 24-bit color BMP format images [2,6]. The BMP image is read in 1-pixel units when the program is executed. For convenience, store the RGB information in a structure from left to right, top to bottom [3]. RGB information is a representation of colors in red, green, and blue.

However, RGB information is difficult for humans to intuitively understand, so this program converts colors to the HSV color space expressed by hue, saturation, and value. Go [4].

IV. COLORING

A. ZNCC template matching

Template matching is searching for where a pattern similar to the template image exists in the whole image (see Fig. 1) [5].

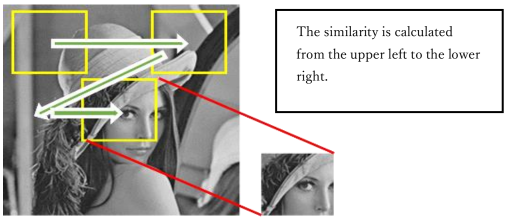

Fig. 1. Template movement.

ZNCC is an abbreviation of "Zero-means Normalized Cross-Correlation", which represents the degree of similarity by the cross-correlation coefficient of the image, input pixel value is I(x,y), template pixel value T(x,y), scanning If the position is represented by d_x, d_y, it is represented by equation (1).

$$ZNCC(d_x, d_y) = \frac{\Sigma\Sigma[I(d_x + x, d_y + y) - \mu_I][T(x, y) - \mu_T]}{\sqrt{\Sigma\Sigma[I(d_x + x, d_y + y) - \mu_I]^2}\sqrt{\Sigma\Sigma[T(x, y) - \mu_T]^2}} \quad (1)$$

$$\Sigma\Sigma = \Sigma_{x=0}^{w} - 1\Sigma_{y-0}^{h-1}$$

μ_I and μ_T are average values of pixel values of the input image and the template image, respectively.

The value of ZNCC falls within -1.0 to 1.0, and the scanning position closest to the maximum value 1.0 is the upper left coordinate of the part where the input image and the template image are most similar [6].

B. Color propagation

After transferring the color, as the color propagation, an edge is detected from the V value of the black and white image and the number of tones is changed to create a filter, and the H value and the S value at the same V value adjacent to the pixel to which the color is transferred are created. Change the value. After that, the pixels whose hue has not changed are searched for in the surrounding pixels (maximum 3×3) if there is a pixel whose hue has changed. At this time, as shown in Fig. 2 (see Fig. 2), a square that is the outer circumference of the target pixel is searched so as to draw a vortex from the inside to the outside.

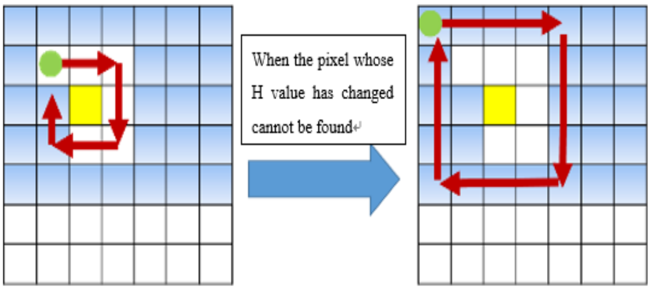

Fig. 2. H-value search movement centered on the target pixel.

If a pixel whose hue has changed can be found, the difference between the V value of that pixel and the target pixel V is compared, and if it is below the threshold value, the H value and S value of the target pixel are changed. Note that the H element does not have the concept of black, gray, or white, so it is necessary to perform processing accordingly. In the processing, black, gray, and white are determined based on the S value and the V value drawn when the H conversion is performed, and the S value is set to 0 when it is determined that they are. Furthermore, since the V value of a monochrome image is low overall, it is necessary to give a constant value to all pixels. This program gives a constant.

V. RESULT

The development environment is as follows.

- OS: Microsoft Windows 10
- Environment: gcc (MinGW.org GCC-8.2.0-3) 8.2.0
- Programming language: C
- Image: BMP image (24bit color)

Table- I show examples of images colored by this program.

The (a) is the black and white image, (b) is the template image, and (c) is the colored image. (d) shows the ideal image (see Table- I).

Table- I: Result

A	B	C
(a) Black And white image		
(b) template image		
(c) colored image		
(d) The ideal image of coloring of execution result		
The average execution time	5.64 seconds (10 times average)	3.55 seconds (10 times average)

VI. CONSIDERATION

We performed template matching using ZNCC using the brightness information of the black and white image and the template image. The coordinates of the starting point with the highest ZNCC value and the highest similarity were (y, x) = (36, 47) in execution B (Table- I) and (37, 48) in execution C (Table- I). Therefore, color propagation near the template image can be performed neatly (see Table- I). However, as far as comparing the colored images (c) of B (Table- I) and C (Table- I) with the ideal colored image (d), the color propagation method using the edge detection by the Sobel filter and the change of the brightness gradation is applied to a place where the difference in brightness is large or a place similar to the hue and the brightness. The area of an edge point could not be divided correctly. For this reason, it is not possible to perform a clean color transmission as the distance from the pixel to which the color is transferred from the template increases.

VII. AT THE END

This time, we performed a restoration method using a black-and-white image with similar brightness values from color information lacking pixels. However, the result was that it was not possible to color it well in some places. We believe that this can be improved by trying better area matching methods. In the program created this time, it was not possible to specify the area to be colored, such as specifying the area that you do not want to paint, such as the background, or coloring only the target part. The ultimate goal of this research is to make these not only color versions of black-and-white images but also similar images as the user wants. In addition, future developments such as pixel area matching using image features, color recoloring using two similar color images, and colorization of moving images and cartoons are expected. Furthermore, in recent years, research on colorization using deep learning has been actively conducted [7]. In addition, it depends on the user whether the image acquired by colorization is what the user wants. Evaluation scales such as what kind of image the colorization result required by the user is are also unavoidable problems in the development of colorization.

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