Color Homogenization of the Color Cryosection Images Based on Color Transfer

Yu Wei, Xuemei Li, Yuanfeng Zhou and Jie Wang
School of Computer Science and Technology, Shandong University, Jinan, China

Abstract: Color inhomogeneity is a known issue in serial cryosections, but there has not been a simple and effective method to solve this problem yet. A new method is proposed to reduce color inhomogeneities in this study, which is based on color transfer technique. It takes advantage of the similarity of adjacent images in image series. The new method can unify the color styles of adjacent slices to achieve the color homogenization of the image series. The color correction process of our method only needs the calculation of mean and standard deviation of pixels of the image. So the new method is simple and highly-efficient. By the multiplanar reformation images, the experimental result shows that the new method has a good performance.

Keywords: Color correction, color characteristic, multiplanar reformation, serial cryosections, visible human project

INTRODUCTION

Visible Human Project (VHP) is the creation of complete, anatomically detailed, three-dimensional representations of the normal male and female human bodies (Ackerman, 1995). It promotes the development of human medicine very much. Color images of the anatomical cryosections are the most important dataset in VHP. Various projects to make the dataset more useful for educational purposes are under way. These applications require that data sets should be as accurate as possible.

Image pre-processing is a necessary step to improve the quality of the dataset. It includes three works: spatial registration, de-noising and color homogenization. Registering is easy to accomplish, because several poles were put around the frozen cadavers. For de-noising, there are a large number of mature technologies. Color homogenization is the most important step of pre-processing, but there is no satisfying solution currently.

The problem of color inhomogeneity can be clearly shown by Multiplanar Reformation (MPR) of the slices. Figure 1 shows a MPR image of chest images in the crown direction. Transverse striation is clearly seen in the whole image. This phenomenon was described in detail in the studies (Marquez and Schmitt, 1996, 2000), in which many experiments had been done to visualize color inhomogeneity of the images. Color inhomogeneity not only makes the MPR images having a poor quality, but although reduces the result quality of other visualization methods. It affects observation of body tissues. Marquez and Schmitt (2000) had provided some reasons which lead to color inhomogeneity of the dataset, but most of the reasons were guessed or estimated. There are a variety of factors in photographing leading to this problem, such as ambient lighting, flash instability, ambient temperature, time exposing to the air, inconsistent camera parameters and uneven alcohol in the surface.

Two methods have been proposed to solve this problem. The first method is to use a test card with standard colors, which is put on the cross section and then is captured with the cross section. Therefore, standard colors can be extracted from the images for camera calibration. The method is based on gamma correction technique. Due to the limited number of standard colors extracted and the imprecision of color values, there remain some color discontinuities between images after the correction. The second method is proposed by Marquez and Schmitt (1996, 2000). A first-order autoregressive model was proposed to achieve local adaptive homogenization and it was based on the information of local histogram. There are three shortcomings of the approach. First, local histogram may lead to local optimum and the color correction lacks integrity. Second, the parameters used in the method cannot be set intuitively. Third, the autoregressive model easily leads to error diffusion.

A variety of interfering factors make it difficult to assess the impact to the color of slice images. So we don't take into account of the role of individual factors, but we take the various factors as a single action. We design a method to weaken its role. VHP dataset can be seen as an image sequence, which has the same color characteristics. Color transfer technique can be used to process the images of the dataset to achieve the desired effect.
Note that in this study: Is denotes the original image, space conversion; second, statistics and color correction. Generally, there are two tasks in the method: first, color characteristics of the target image. Composite image will keep scene of the source image and characteristics from another. In the ideal case, the color correction that borrows one image's color information will make a synthetic image look and feel. So it is a method for a general form of color transfer is changing the color distribution of data points in the image to its adjacent images. For an image in the sequence, its adjacent images on both sides have the largest similarity. In other words, if we select an image Is in the sequence as the source image, the target image It is the image to its adjacent images. For an image in the sequence, its adjacent images on both sides have the largest similarity. In other words, if we select an image Is in the sequence as the source image, the target image It is the image to its adjacent images. The result’s quality of Reinhard et al. (2001) method depends on the images' similarity in composition. Many studies had been done to solve the problem that unnatural looking results will be produced when there are much difference between the color distributions of the source image and the target image. But we don't very care about this problem, because the adjacent images in the dataset have great similarity of the color distribution.

Color homogenization of adjacent images: To make the whole series images color homogenization, a basic step is to make several adjacent images color homogenization. In order to do this, we need to make an image having the average color characteristics of its adjacent images. So we introduce a basic method of color correction to transfer an image to its adjacent images. For an image in the sequence, its adjacent images on both sides have the largest similarity. In other words, if we select an image Is in the sequence as the source image, the target image It is the image to its adjacent images. The result image takes on original source look and feel.

**Materials and Methods**

**Color transfer between images:** We begin by briefly summarizing the Reinhard et al.'s color transfer method (Reinhard et al., 2001). Color transfer is one of the most common tasks in image processing. The goal of color transfer is to make a synthetic image take on another image look and feel. So it is a method for a general form of color correction that borrows one image's color characteristics from another. In the ideal case, the composite image will keep scene of the source image and the color characteristics of the target image.

**Color space conversion:** An uncorrelated color space (CS) Ruderman et al. (1998) is used in Reinhard et al. (2001) method. First, the RGB signals of an image are converted to CIE 1931 XYZ color space (Thomas and Guild, 1931); second, the XYZ signals are converted to LMS cone space (Wyszecki and Stiles, 1982 a,b); finally, the LMS signals are converted to the perception-based color space (CS). The entire conversion process is reversible, so CS can be converted back to color space RGB easily.

**Statistics and color correction:** The core of color transfer is changing the color distribution of data points in (CS) space from I, to I, . The mean and standard deviation of the pixels in I, can be calculated in each channel, where . In the same manner, and of I, can be calculated.

There are three steps of color correction:

1. Subtract the mean from the pixels of I:

   \[ \xi = \xi - \mu, \xi \in \{t, \alpha, \beta\} \]  

2. Scale the pixels by factors determined by the respective standard deviations:

   \[ \xi = \frac{\sigma_i}{\sigma_t} C_t, \xi \in \{t, \alpha, \beta\} \]  

3. Synthesize the corrected image I:

   \[ \xi = \frac{\sigma_i}{\sigma_t} C_t, \xi \in \{t, \alpha, \beta\} \]  

**Color transfer:** The input image I, and I, are converted from the color space RGB to (CS) firstly. Then , and are calculated. The color correction is done to get the corrected image I, which is converted form the color space (CS) to RGB. The result image takes on original source look and feel.

In the simplest case, the adjacent images are on the left side and right side of I, Fig. 2. So they are the target images. The center image is denoted by , and the left and right image are denoted by I and I, respectively. We can calculate their means and their standard deviations , , and , \( \xi \in \{t, \alpha, \beta\} \). In order to ensure that
Ic has the average color characteristics of its adjacent images, the result image Ic should have the average color distribution of Il and Ir. We use \( \bar{\xi} = \frac{\bar{\xi}_l + \bar{\xi}_r}{2} \) as the target mean and use \( \sigma^c_l = \frac{(\sigma^c_l + \sigma^c_r)}{2} \) as the target standard deviation. It should be pointed out that \( \sigma^c_l \) is not the standard deviation of all the pixels of Ic and Ir. The standard deviation can't be calculated through \( \sigma^c_l \) and \( \sigma^c_r \) directly. It must be recalculated by statistics of all the pixels of Il and Ir, which is too much time consuming. So we use the average standard deviations of Il and Ir to obtain an approximate value instead. In practice, the effect of the method is acceptable.

The formulas for the color correction of adjacent images are:

\[
\xi' = \frac{(\xi_l + \xi_r)}{2} \quad C_s, \xi \in \{\alpha, \beta\}
\]

(4)

\[
\xi' = \bar{\xi} + \frac{(\bar{\xi}_l + \bar{\xi}_r)}{2}, \xi \in \{\alpha, \beta\}
\]

(5)

We can find that the fundamental principle of our method corresponds with (Reinhard et al., 2001) method and the computational complexities of them are same too.

**Color homogenization of series images:** By expanding the color transfer method for adjacent images, we find a way to achieve color homogenization for series images. To some extent, the whole image series has same holistic color characteristics. The mean and standard deviation of the whole series can be calculated. But they are less meaningful for color transfer. Because the content of the first image in the series are very different from that of last image. When the source image is very different from the target image, color transfer may fail. The result quality depends on the images similarity in composition (Reinhard et al., 2001). For a image, only several left and right adjacent images may have greatly similarity. So we select the left and right adjacent images of each image in the series as the target images and do color correction.

If \( \{I_1, I_2, ..., I_{m}, I_{m+1}, ..., I_{1}, I_2, ..., I_{m}, ..., I_{m+1}, I_1\} \) is a cryosection image series, \( \{I_{m}, I_{m+1}, ..., I_{1}, I_2, ..., I_{m}, ..., I_{m+1}, I_1\} \) will be a part of the series. This part has \( 2m+1 \) images, which should have greatly similarity if m is not very large. We let \( I_1 \) be the source image \( I_s \) and other \( 2m \) images be the target images.

The formulas for the color correction of a part of the series are:

\[
\xi' = \frac{\sum_{k=m+1}^{m} \sigma^c_k + \sum_{k=1}^{m} \sigma^c_k}{2m\sigma^c}, \xi \in \{\alpha, \beta\}
\]

(6)
\[
\xi = \xi_1 + \frac{\sum_{i=1}^{2m} \xi_i + \sum_{i=1}^{2m} \xi_i}{2m}, \xi \in \{e, \alpha, \beta\} \quad (7)
\]

We do color correction for each image in the series with its 2m adjacent images. So each image will have the color characteristics of the nearby part of the series. Therefore the complete series are more homogenization after the color correction. We can repeat this process several times to make the series homogenized enough. The parameter \(m\) controls the degree of homogenization and it should not be very large. We compare the different results in Fig. 3, when \(m\) is set to different value.

The overall algorithm of color homogenization for a series is as follows:

- Convert all the images in the series to color space \(\xi_1\).
- While the series is not homogenized enough:
  - Calculate the means and standard deviations of the images.
  - Calculate the difference with the mean of each image, using Eq. (1).
  - Scale each image by factors determined by the standard deviations, using Eq. (6).
  - Synthesize the corrected images, using Eq. (7).
- Convert all the images in the series from the color space \(\xi_1\) to RGB.

**EXPERIMENTAL RESULTS**

We apply our method to a cryosection series. These images have been registered in spatial location. But they were not calibrated using standard color test cards. We select two parts (head and chest) of the cryosection series to show the effect of our method. Each of parts has 200 color images. We compare the results of our method with that of Marquez's method. From the MPR images in the crown direction shown in Fig. 3, we can find that our color transfer method performs better than Marquez's method. Transverse striation can be eliminated very well when using our method. As \(m\) increases, the color of MPR image is more homogenized. Especially, when \(m = 7\), transverse striation are almost completely eliminated. This improve the image quality and the observed effects greatly.

**CONCLUSION**

A novel color homogenization method is proposed in the study. It is based on color transfer technique. The new method can overcome the color inhomogeneity problems caused by a variety of uncertainly factors in the color cryosection image series. Experimental results show that our method can eliminate transverse striation in the MPR image very well. The new method can adjust image color without regarding to the factors and it is more reliable and efficient. Besides, it is more adaptability and flexibility than Marquez's method.

**ACKNOWLEDGMENT**

This study is supported by National Research Foundation for the Doctoral Program of Higher Education of China (20110131300004) and National Science Foundation of China (61103150).

**REFERENCES**


