Research Journal of Applied Sciences, Engineering and Technology 4(22): 4761-4764, 2012
ISSN: 2040-7467

Submitted: April 07, 2012 Accepted: April 25, 2012 Published: November 15, 2012

Color Homogenization of the Color Cryosection Images Based on Color Transfer

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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.

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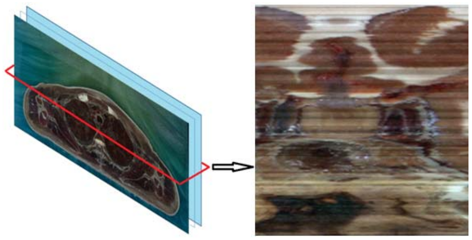


Fig. 1: A part of the MPR image of chest cryosection slices in the crown direction

There are three contributions in this study:

- A global method is used to change the color characteristics of each image and the color consistency of each image is well maintained.
- The color correction of each image considers only several adjacent images in the series. This eliminates the error diffusion.
- The proposed method only needs to calculate the mean and standard deviation of each image. So it is very simple and efficient.

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.

Reinhard *et al.* (2001)'s method is very simple. Generally, there are two tasks in the method: first, color space conversion; second, statistics and color correction. Note that in this study: I_s denotes the original image, which will be corrected; I_t denotes the target image, which has the target color style; I_c denotes the corrected image.

Color space conversion: An uncorrelated color space $\ell\alpha\beta$ 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 $\ell\alpha\beta$. The entire conversion process is reversible, so $\ell\alpha\beta$ signals 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 $\ell\alpha\beta$ space from I_s to I_t. The mean $\overline{\xi_s}$ and standard deviation σ_s^ξ of the pixels in I_s can becalculatedin each $\ell\alpha\beta$ channel, where $\xi \in \{\ell, \alpha, \beta\}$. In the same manner, $\overline{\xi_t}$ and σ_t^ξ of I_t can be calculated.
There are three steps of color correction:

- Subtract the mean $\overline{c_s}$ from the pixels of I_s:

$$\xi_s^* = \xi_s - \overline{\xi_s}, \xi \in \{\ell, \alpha, \beta\} \tag{1}$$

- Scale the pixels by factors determined by the respective standard deviations:

$$\xi_t^{'} = \frac{\sigma_t^\xi}{\sigma_s^\xi} C_s^*, \xi \in \{\ell, \alpha, \beta\} \tag{2}$$

- Synthesizethe corrected image I_c:

$$\xi_c = \xi_t^{'} + \overline{\xi_t}, \xi \in \{\ell, \alpha, \beta\} \tag{3}$$

Color transfer: The input image I_s and I_t are converted from the color space RGB to $\ell\alpha\beta$ firstly. Then $\overline{\xi_s}$, $\overline{\xi_t}$, σ_s^ξ and σ_t^ξ are calculated. The color correction is done to get the corrected image I_c, which is converted form the color space $\ell\alpha\beta$ to RGB. The result image takes on original source look and feel.

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 I_s in the sequence as the source image, the target image I_t is not a signal image, but its adjacent images. Reinhard *et al.*, (2001) method can only process a single reference image. So the method is changed to meet the challenge.

In the simplest case, the adjacent images are on the left side and right side of I_s, Fig. 2. So they are the target images. The center image is denoted by I_s, and the left and right image are denoted by I_l and I_r, respectively. We can calculate their means $\overline{\xi_s}, \overline{\xi_l}, \overline{\xi_r}$ and their standard deviations $\sigma_s^\xi, \sigma_l^\xi, \sigma_r^\xi$, $\xi \in \{\ell, \alpha, \beta\}$. In order to ensure that

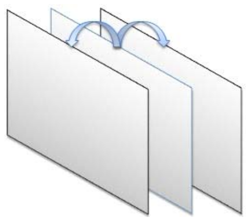


Fig. 2: Adjacent left and right images as the target images

I_s has the average color characteristics of its adjacent images, the result image I_c should have the average color distribution of I_l and I_r. We use $\overline{\xi_t} = \left(\overline{\xi_l} + \overline{\xi_r}\right)/2$ as the target mean and use $\sigma_t^{\xi} = \left(\sigma_l^{\xi} + \sigma_r^{\xi}\right)/2$ as the target standard deviation. It should be pointed out that σ_t^{ξ} is not the standard deviation of all the pixels of I_l and I_r. The standard deviationcan't be calculated through σ_l^{ξ} and σ_r^{ξ} directly. It must be recalculated by statistics of all the pixels of I_l and I_r, which is too much time consuming. So we use the average standard deviations of I_l and I_r 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:

$$\xi_t' = \frac{\left(\sigma_l^{\xi} + \sigma_r^{\xi}\right)/2}{\sigma_s^{\xi}} C_s^*, \xi \in \{\ell, \alpha, \beta\} \tag{4}$$

$$\xi_c = \xi_t' + \left(\overline{\xi_l} + \overline{\xi_r}\right)/2, \ \xi \in \{\ell, \alpha, \beta\} \tag{5}$$

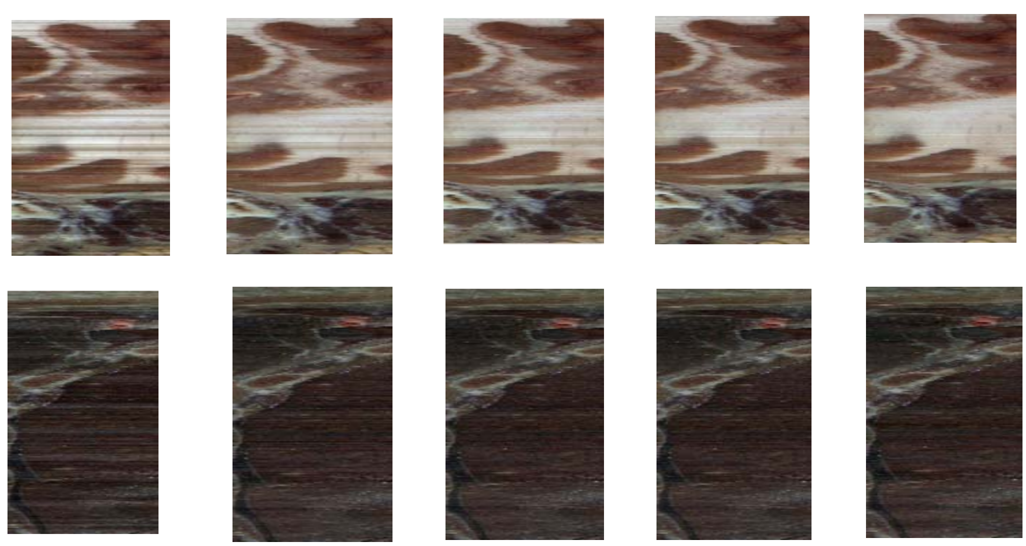
We can find that the fundamental principle of our method corresponds with (Reinhard *et al.*, 2001) method and the computational complexities of them are same too.

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 form 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 $\{I_1, I_2, ..., I_{i-m}, I_{i-m+1}, ..., I_{i-1}, I_i, I_{i+1}, ..., I_{i+m-1}, I_{i+m}, ..., I_{n-1}, I_n\}$ is a cryosectionimage series, $\{I_{i-m}, I_{i-m+1}, ..., I_{i-1}, I_i, I_{i+1}, ..., I_{i+m-1}, I_{i+m}\}$ 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_i be the source image I_s and other 2m images be thetarget images.

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

$$\xi_t' = \frac{\sum_{k=i-m}^{i-1} \sigma_k^{\xi} + \sum_{k=i+1}^{i+m} \sigma_k^{\xi}}{2m\sigma_s^{\xi}} C_s^*, \ \xi \in \{\ell, \alpha, \beta\} \tag{6}$$



a original *b* Marquez's cm = 3 dm = 5 en = 7

Fig. 3: The MPR images obtained from original chest cryosection slices and processed slices using color transfer method and Marquez's method

$$\xi_c = \xi_t' + \frac{\sum_{k=i-m}^{i-1} \overline{\xi_k} + \sum_{k=i+1}^{i+1} \overline{\xi_k}}{2m}, \xi \in \{\ell, \alpha, \beta\} \tag{7}$$

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 $\ell\alpha\beta$.
- 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 $\ell\alpha\beta$ to RGB.

EXPERIMENTAL RESULTS

We apply our method to a cryosection series. These images have been registered in spatiallocation. 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 improvesthe 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 (20110131130004) and National Science Foundation of China (61103150).

REFERENCES

Ackerman, M., 1995. The Visible Human Project. Retrieved from: http://www.nlm.nih.gov.

Marquez, J. and F. Schmitt, 1996. Color correction of color cry section images for three-dimensional segmentation of fine structures. In Visualization in Biomedical Computing: Proceedings of 4th International Conference, VBC’96, Hamburg, Germany, September 22-25, Springer Verlag, pp: 117.

Marquez, J. and F. Schmitt, 2000. Color homogenization of the color cry section images from the VHP Lungs for 3D segmentation of blood vessels. Comput. Med. Imag. Graph., 24(3): 181-191.

Reinhard, E., M. Ashikhmin, B. Gooch and P. Shirley, 2001. Colortransfer between images. IEEE Comput. Graph. Appl., pp: 34-41.

Ruderman, D., T. Cronin and C. Chiao, 1998. Statistics of cone responses to natural images: Implications for visual coding. J. Opt. Soc. Am. A, 15(8): 2036-2045.

Thomas, S. and J. Guild, 1931. The C.I.E. colorimetric standards and their use. Trans. Opt. Soc. 33(3): 73-134.

Wyszecki, G. and W.S. Stiles, 1982a,b. Color Science: Concepts and Methods, Quantitative Data and Formulae. 2nd Edn., John Wiley and Sons, New York.