Spectral Image Reconstruction of Chinese Ink and Wash Painting Based on Self-training with Multispectral Imaging

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ABSTRACT

The Chinese ink and wash painting is a special type of Chinese classic paintings. In this study, the spectral image of the Chinese ink and wash painting was reconstructed with multispectral imaging based on a self-training method. By partitioning the multispectral images of the painting with k-means clustering algorithm, the training samples are directly selected from the painting itself to restrain the deterioration of the spectral estimation caused by the material inconsistence between the training samples and the object painting in the conventional spectral reconstruction technique. In each cluster, only one sample which owns minimum mean distance to all the other samples residing in the cluster is chosen as the training sample. The spectral image of a Chinese ink and wash painting was reconstructed with a filter wheel based multispectral camera, indicating that the recovered spectral reflectance of the Chinese ink and wash painting based on this self-training method is more accurate than that based on the commercial color target.

KEYWORDS: Spectral Image Reconstruction, Self-Training, Chinese Ink and Wash Painting

INTRODUCTION

As a non-invasive imaging technique, multispectral imaging has been applied to the field of art painting conservation for its capability of accurately acquiring the spectral image which contains pixel-wise spectral reflectance[1-3]. The spectral reflectance can be recovered through certain spectral estimation algorithms[4], most of which are training based, i.e., the training samples composed of spectral reflectances and the corresponding multichannel camera responses are necessary to build the transforming model converting multichannel camera responses to spectral reflectance. However, most commercial targets do not encompass the spectral properties of the specific art painting to be imaged. For art painting conservation, an alternative approach to weaken the influence of material inconsistence is to paint color patches with the pigments close to those used in the target[5], while the colors of painting depend not only on the pigments but also on the binding medium, surface absorbency, texture of the finish, size of particles, substrate, and etc. To leave out making color target by painting color patches and alleviate the deteriorations of reflectance recovery caused by material inconsistence, a self-training based spectral reflectance recovery method was developed for accurately reconstructing the spectral images of art paintings in this study. The training samples are extracted from the art painting itself by partitioning the multichannel responses with k-means clustering algorithm. The spectral image of a Chinese ink and wash painting was reconstructed with the proposed method upon a filter wheel based multispectral camera.

METHODS

The flow chart of the training sample extraction is illustrated in Fig. 1. The multispectral images of the target painting are captured by a multispectral camera, then the painting is covered by a coordinate paper tightly. Subsequently, the multispectral images of the coordinate paper are acquired under the same capture setting and environment.

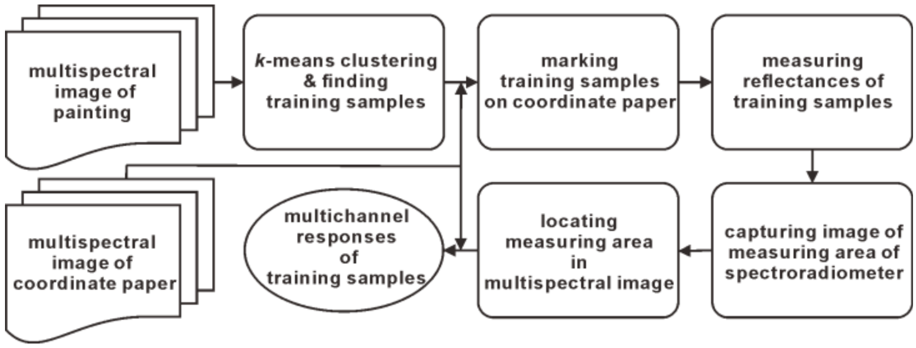

Figure 1: The flow chart of training samples extraction for art painting.

By clustering the multichannel responses of the painting with k-means algorithm, the multispectral images of the painting are divided into several clusters. In each cluster, the representative sample is selected as one training sample, i.e. the pixel owning the minimum distance calculated based on the multichannel responses to any other sample in this cluster. Thus, the number of training samples equals to the number of clusters. The positions of the training samples on the multispectral images of painting are mapped to the multispectral images of coordinate paper, and then the training samples are marked on the coordinate paper. Next, the spectral radiance of the training sample is measured with the spectroradiometer, then the spectral radiance of a reference board with known reflectance fixed where the training sample is is measured. Hence, the spectral reflectance of the training sample can be calculated with the spectral reflectance of the reference board and the spectral radiance of the reference board and the training sample.

The circle measuring area of the spectroradiometer upon the coordinate paper is captured by a commercial camera through the ocular of the spectroradiometer. Then in the captured image, the circle Hough transform is executed to acquire the circle measuring area. The pixels corresponding to the measuring area of the spectroradiometer in the multispectral image of the painting can be confirmed with the help of the multispectral image of the coordinate paper. Finally, the mean multichannel responses of all the determined pixels within the measuring area are calculated as the multichannel responses with respect to the training sample. Based on the multichannel responses and spectral reflectances of the extracted training samples, the transform model converting the multichannel camera responses to spectral reflectance for the art painting can be established, upon which the spectral image of the art painting could be reconstructed.

EXPERIMENTS AND RESULTS

The kernel algorithm[6] was adopted to recover the spectral reflectance of the painting from its corresponding multichannel camera responses. Meanwhile, the correlation distance combinations were adopted in both the processes of clustering and selecting training samples. A typical multispectral camera was employed, equipped with 8 filters of nominal 20 nm FWHM mounted in a filter wheel between a lens and a monochromatic CCD. The Konica Minolta CS-2000 spectroradiometer was used to measure the spectral radiance reflected from the training sample on the painting and that of the reference board, and the spectral reflectance of the reference board was measured by the X-Rite spectrophotometer SP64. An 8-bit RGB camera was adopted to capture the measuring area of CS-2000 through its ocular. A Chinese ink and wash painting was tested in the experiment, as illustrated in Fig. 2.

As indicated by the green dots in Fig. 2(a), 15 training samples were extracted from the Chinese ink and wash painting. Figure 2(b) shows the sRGB reproduction for the reconstructed spectral image of the tested painting with the 15 training samples. In addition, 10 testing samples were also extracted from the painting to verify the accuracy of the spectral reflectance recovery, as marked by the red dots in Fig. 2(b). Meanwhile, the commercial target X-Rite Digital ColorChecker SG (DSG) chart was also employed as the training samples to compare the performance of spectral estimation. Figure 3 illustrates the recovered spectral reflectance curves of the 10 testing samples based on the two sets of training samples, respectively. The solid line represents the measured reflectance, and the dashed line indicates the recovered spectral reflectance with DSG chart, while the dash-dotted line plots the recovered reflectance with the 15 extracted training samples (called sefl-training). As demonstrated in Fig. 3, the spectral reflectances recovered with the extracted training samples are closer to the measured ones than those recovered with DSG chart for the Chinese ink and wash painting.

(a) (b)

Figure 2: (a) The 15 training samples in the 540 nm channel image of the painting, and (b) the sRGB representation of the reconstructed spectral image for the painting under CIE D65 illuminant and 2° observer.

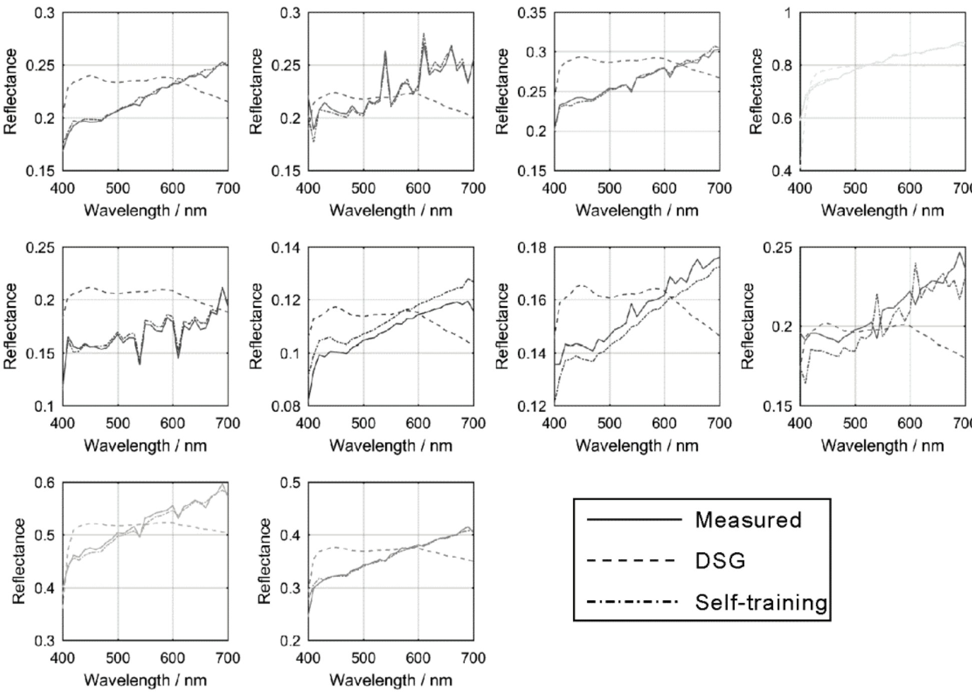

Figure 3: The recovered spectral reflectance curves with the DSG chart and the extracted training samples.

The detailed spectral estimation errors on basis of the two training sets are tabulated in Table 1. The mean values of RMSE, GFC, ΔE_{00}-D65 and ΔE_{00}-A achieved with the extracted training samples are all obviously lower (or higher for GFC) than those calculated with DSG chart. Thereby, the extracted training samples are more effective for spectral reflectance recovery in comparison with the DSG chart.

Table 1. Spectral estimation accuracy for the 10 testing samples based on the two training sets.

		DSG	Tr
RMSE	Mean	0.0334	0.0060
	Std.	0.0203	0.0030
	Max.	0.0678	0.0136
GFC	Mean	0.9929	0.9997
	Std.	0.0097	0.0005
	Min.	0.9746	0.9984
ΔE_{00}-D65	Mean	5.61	0.66
	Std.	4.39	0.32
	Max.	13.92	1.15
ΔE_{00}-A	Mean	5.38	0.63
	Std.	4.42	0.35
	Max.	13.53	1.20

CONCLUSION

The self-training based spectral reflectance recovery method for art painting was developed by extracting training samples directly from the art painting utilizing k-means clustering algorithm. The circle Hough transform was executed in the image captured through the ocular of spectroradiometer to determine its measuring area, meanwhile the multispectral images of a coordinate paper covered on the painting were captured for locating the training samples in the multispectral images of the painting. The spectral image of a Chinese ink and wash painting was reconstructed with the extracted training samples, which were verified to be able to recover more accurate spectral reflectance for the Chinese ink and wash painting with comparison to the commercial target.

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