Multispectral Image Acquisition of Paintings Drawn with Natural Mineral Pigments and Its Application

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Abstract

Many of old Asian paintings have been drawn with natural mineral pigments. The digital archive of those paintings, the identification of pigments used in the paintings and the retrieval of color fading are strongly desired. The multispectral image acquisition of those paintings allows the digital archive of accurate color information of objects. Moreover, it has a potential of identification of used pigments and leads to the possibility of the retrieval of color fading. This paper describes our first trial of statistical analysis of the reflectance spectra of natural mineral pigments, image acquisition of those paintings by a multispectral camera and the construction of the GUI based segmentation tool for the aid of analysis of paintings.

Introduction

Multispectral image acquisition of historically or archeologically valuable paintings is very important in the sense of archive and analysis. Digital archive in a form of spectral reflectance image allows the accurate color reproduction of those paintings in the current status in future [1]. On the other hand, as analysis the identification of the used pigment or the estimating the way of making use of those pigments might be possible from the multispectral images [2]. In fact, infrared imaging, fluoroscope imaging or X-ray spectral analysis have been done for the analysis purpose. However, the multispectral images over visible range should also contribute the analysis complementarily.

Many of old Asian paintings such as wall paintings in ancient tombs or Buddhist images have been drawn with natural mineral pigments. However, very few study on the multispectral image acquisition for those subjects have been done so far. The digital archive of those paintings, the identification of used pigments and the retrieval of color fading are strongly desired. This paper describes our first trial of statistical analysis of the reflectance spectra of natural mineral pigments, image acquisition of those paintings by a multispectral camera and the construction of the GUI based segmentation tool for the aid of analysis of paintings.

Data acquisition

Measurement of Reflectance Spectra

Samples of natural mineral pigment were collected and those reflectance spectra were measured. The number of samples collected is 51, which include azurite, corundum, agate, jasper, etc. Reflectance spectra are shown in Fig. 1. There was a sample showing a strong fluorescence. In the following analysis, that sample was removed. It is observed that reflectance spectra have smooth shape similar to those of the oil paintings [3].

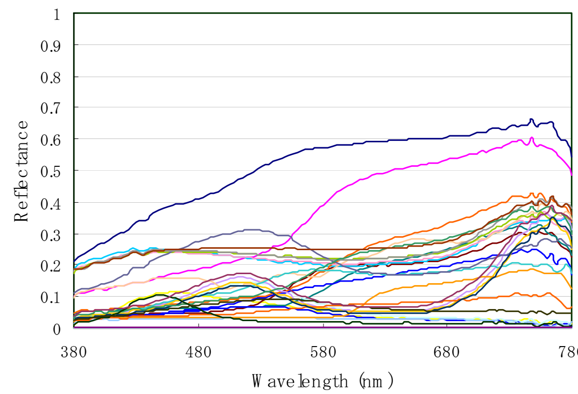

***Figure 1**. Reflectance spectra of natural mineral pigment samples.*

Principal component analysis was performed for these samples. Cumulative contribution ratio (CCR) is shown in Table 1. The result shows that the first three components can represent the original spectral reflectance with 98.7 % of accuracy.

Table 1 Cumulative contribution ratio of reflectance spectra of natural mineral pigments.

# of PCs	1	2	3	4	5	6
CCR (%)	84.0	96.4	98.7	99.6	99.8	99.9

Grain size dependent property of reflectance

Natural mineral pigments are made by grinding a stone into very small grains and the color depends on the size of grain. Generally the smaller the gain is, the less saturated the color is. Currently, each of commercially available natural mineral pigment has a number related to the grain size, where the larger number corresponds to smaller grain.

For the purpose of pigment identification, the stable classification independent from the grain size is desired. So we first investigated for seven kinds of pigments how the spectral reflectance of the pigment varies depending on its grain size. Figure 2 shows the result for four pigments. Each pigment has five levels of grain sizes. The tendency is observed that smaller grain pigments have higher reflectance. However, it looks difficult to apply a simple reflectance model to those data. This time, we just tried to have a logarithm of the reflectance and then subtract the average value from it. Figure 3 shows the results. The dispersion is somewhat reduced. Further investigation for the modeling of reflectance and development of proper normalization based on it are required.

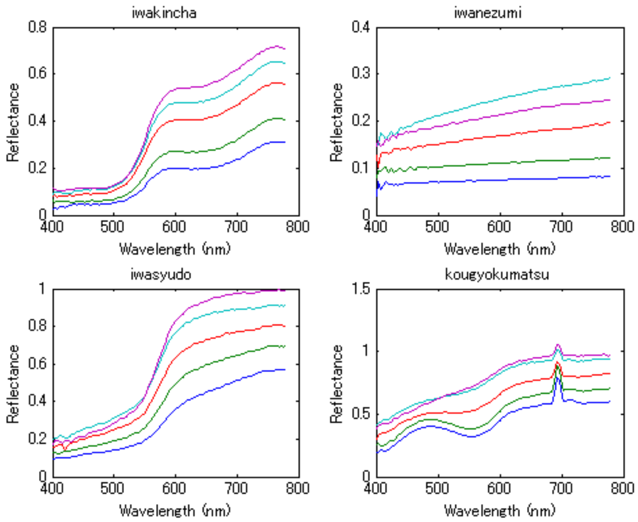

Figure 2. *Grain size dependent reflectance spectra of natural mineral*

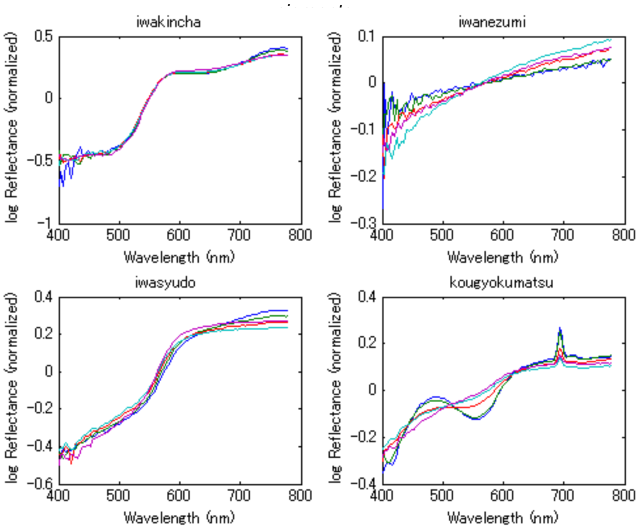

Figure 3. *Normalized reflectance spectra of natural mineral pigments.*

Multispectral Image Acquisition

Multispectral image acquisition for some paintings of Buddha was performed with a 16-band camera developed by the Natural Vision project. Figure 4 shows the image acquisition experiment.

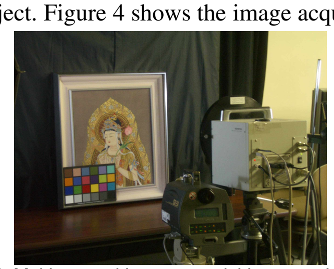

Figure 4. *Multispectral image acquisition experiment using a 16-band camera.*

Segmentation

RGB-based vs. Multispectrum-based segmentation

In this subsection, the effectiveness of the multispectrum based segmentation is demonstrated. The multispectral image of Buddha was clustered into 48 groups in this calculation. RGB color images were generated from the 16 band images and then the same clustering technique was applied to the image. Figure 5 shows reflectance spectra of 12 clusters among 48 clusters. The top and the bottom in the figure represent the RGB based clustering and the multispectrum based clustering result, respectively. This figure clearly shows that each cluster by the multispectral image generally has narrower distribution than the corresponding RGB based cluster. This means that reflectance spectra clustered by multiband images are more similar each other. This property is more suitable for the analysis.

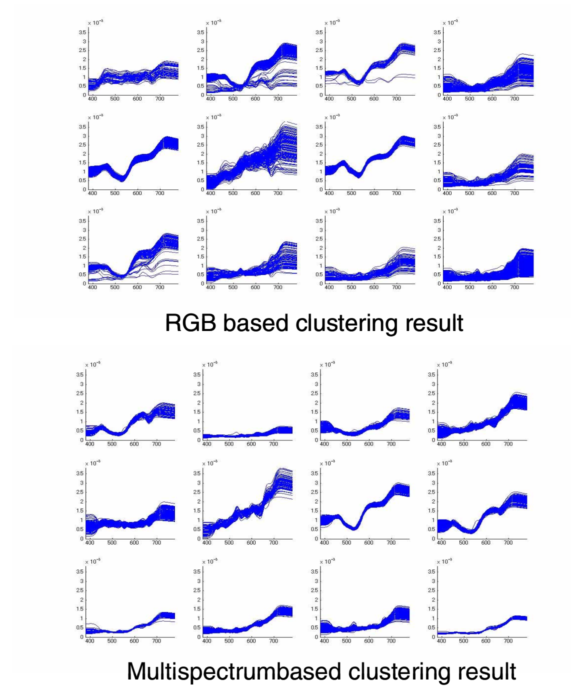

Figure 5. *Comparison of clustering performance between RGB and multispectral images.*

GUI based segmentation tool

We devised a processing flow for segmentation based on spectral reflectance. The flow is shown in Fig. 6. From the originally captured multispectral images, spectral reflectance was estimated pixel-by-pixel using Wiener estimation. The estimated reflectance is then compressed to a smaller dimension subspace using a few principal components. In this case, we used three principal components. For clustering, two-step technique was used [4]. At the first step, the K-means method was used to determine 100 clusters from the original image. This method is appropriate in clustering a large number of data in a relatively small computational burden. At the second step, a hierarchical method was used to reduce the number of the cluster further. This method has an advantage that is robust to the noise.

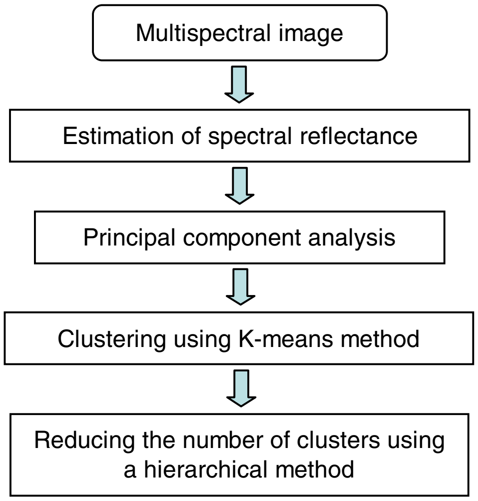

Figure 6. *Processing flow for multispectral image based clustering.*

We then built a GUI based clustering tool as shown in Fig. 7. In this figure, top-left pane and top-right pane respectively show the original image and the clustered image. The number of clusters under 100 can be selected by setting the number in the right box. By pointing a pixel using a mouse on the clustered image, the spectral reflectance at the pixel is displayed onto the bottom right pane. A set of reflectance spectra to which the selected pixel belongs is all displayed onto the bottom left area. Using this tool, an operator can investigate what spectral reflectance the current pixel has, where are the pixels whose spectral reflectance is similar to the current pixel, how similar are those characteristics, etc.

Figure 7.*GUI-based segmentation tool developed.*

Conclusions

We have collected the samples of natural mineral pigments used for painting, e.g., Buddhist images and performed the statistical analysis of the reflectance spectra. Those reflectance spectra have smooth characteristics as observed in oil painting. Comparison between clustering with RGB images vs. clustering with multispectral images was carried out and the effectiveness of using multispectral images was confirmed. The GUI based segmentation tool was also built for the aid of analysis of paintings.

References

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Author Biography

Hiroshi Kouno received BS degree from Chiba University. He is currently a master course student of the graduate school of science and technology, Chiba University. He is studying color image acquisition and processing, computer graphics, and reflectance models.