Materials Investigation through High-resolution Analytical Imaging and Spectrometry

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Research Overview

Analytical imaging refers to the technique which uses image processing, data mining and pattern recognition to extract useful and relevant information about different properties of a material. This is based on the fact that a material subjected to an incident electromagnetic radiation behaves in a predictable and quantifiable way. The characteristic material response depends on the energy and frequency of the radiation. In this study, focus was given to the visible to near infrared range of the electromagnetic spectrum. The material response is quantified based on its spectral properties, colorimetric information and spatial features. It is believed that the most important aspect of an imaging system is the acquisition of the images. Without a good quality image, any processing would be meaningless. Therefore, the main goal of the studies performed in this research is the development and implementation of a nondestructive and noninvasive means of analytical imaging which is capable of acquiring uninterpolated high resolution images able to accommodate small- to large-sized objects.

Selected Results

Cultural heritage refers to artifacts and intangible features inherited from previous generations, which are preserved or maintained for the benefit of future generations. In the past, interests in cultural heritage are mainly based on its aesthetic and historic values. However during the recent years, it has been attracting the attention of scientists and engineers because of the technical challenges it presents during analysis, restoration and preservation. Its delicate nature requires that the investigation should be non-destructive and non-invasive.

There are many analytical techniques used in studying cultural heritage but most of them are high-energy techniques. This kind of techniques requires microsampling which is a no-no for cultural heritage. In this section, multispectral images, ultrahigh resolution image scans and polarized light scans were employed on-the-site for some important authentic cultural heritage. These section features one of the most recent cultural heritage scanning projects with which our laboratory had engaged. This project was done at the Tokyo National Museum .The quality and integrity of the images taken is unparalleled. The information about an object’s color and spectral reflectance was used to identify the material, simulate pigment degradation process and predict original color, which are very useful for restoration and preservation of cultural heritage. Some of the significant results are presented hereafter.

Tokyo National Museum Scanning

The scanning at the Tokyo National Museum involves three types of scanning modes. The scanning modes are: 1) 1200 DPI trichromatic scanning using single and dual lighting; 2) 600 DPI polarized light scanning; and 3) 600 DPI multispectral scanning. There were two objects scanned. The objects are part of the Uji Bridge folding screen panel painting collection. These objects are part of a precious art collection from the Momoyama era. The paintings are believed to be around 400 years old. The object dimension is approximately 3.5m x 1.8m. Since the objects are quite big, it is almost impossible to get good quality images by only using conventional photography. Using the analytical imaging system that was developed as result of this dissertation, this would not be a problem. The object needed to be scanned multiple times then stitched together afterwards. In the case of the 1200 DPI scans, it required about 30 scans. Each scan is about 2GB in file size. Using conventional photo editing software, it is almost impossible to handle these huge image files. A special image editing software called Amateras was used to stitch the images. In the case of the 600 DPI scans, it required 12 scans to capture the entire folding screen panels. The file size is about 900 Mb per image strips. Similarly, the strips were stitched using Amateras. The stitched images of both the folding screen panels are given in Figure 1. Finally, some examples on how the different modes of scanning were used for analysis are given in Figures 2 to 3.

Figure 1: Stitched images of the 1200-DPI scans. The folding panels meant to represent the changes of season as envisioned by the artist. The panels are meant to be displayed as a set: the left-side (top) and the right-side (bottom).

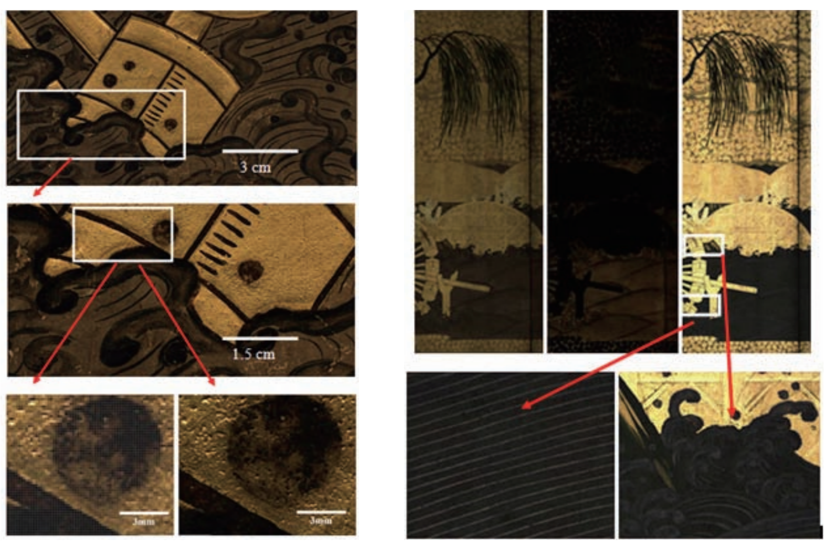

Figure 2: (Left) This figure shows the benefits of a high resolution scan. These images are taken from the 1200 DPI trichromatic scans from Panel 1 of the left-side of the folding screen painting. The bottom two images are comparison of the difference between a high resolution scan and a low resolution scan. The one on the left has a resolution of 300 DPI while the one on the right has a resolution of 1200 DPI. Commercial scanners can only scan at 300 DPI. Even

those offering to be able to scan at higher resolution are actually interpolated image. The 1200-Dpi scan using our system is uninterpolated. (Right): The third mode of scanning was using polarized light. The motivation for doing this is to separate the diffuse from the specular reflections. It can be observed that the painting on the folding panel is predominantly gold. Gold is one of the most difficult objects to image because of its metallic finish that results to very high specular reflections. Since specular reflection is highly directional, it is possible to eliminate it by using the right viewing angle. Two types of polarization were employed to make this possible. The first polarizer (linear polarizer) is placed in front of the light source and then a second polarizer (circular polarizer) is placed in front of the camera. Using mathematical calculations using the Lambertian model, it became possible to separate the diffused from the specular reflections. The three images on the top are examples of the results. The one on the far left is an image with combined specular and diffused reflections. The one in the middle shows only the diffused reflection components. Then the one on the far right contains only specular reflections. There are two types of metallic components found on the painting. The first one is gold which is shown at the right side of the bottom two images. The other metallic component is silver which was used to create the wave patterns found in the folding screens. It is important to note that no other modes of scanning were able to detect this level of detail from the silver components. With the other modes, the wave patterns only appeared to be black due to severe discoloration. However, with the polarized scanning, it was very easy to detect.

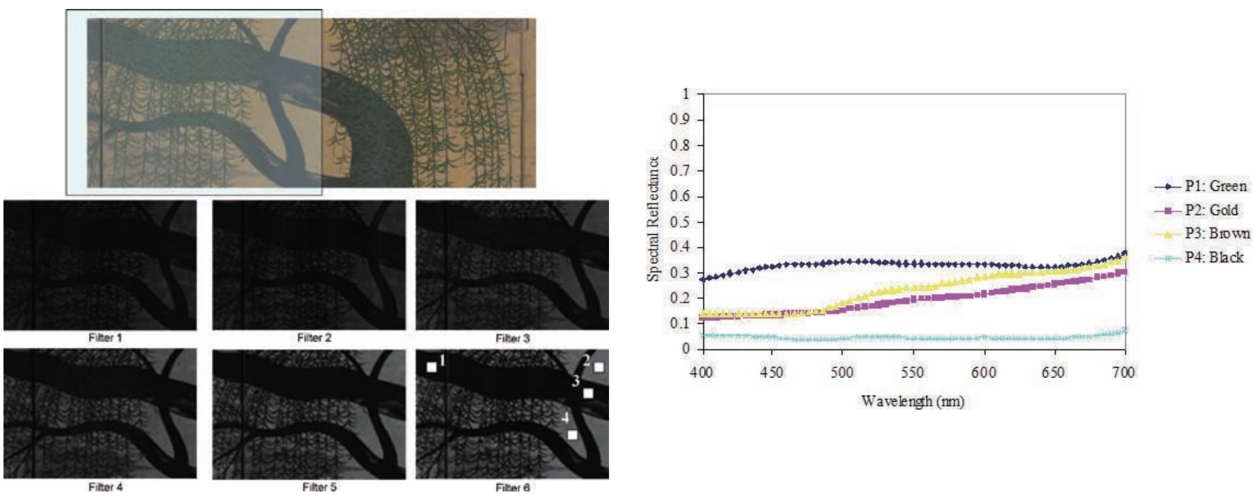

Figure 3: The second mode of scanning on the Uji Bridge folding screen panels is multispectral scanning. This figure shows the monochromatic images from the multispectral scans. This figure also shows a reconstructed trichromatic image of a portion of the 5th panel of the left side of the folding screens.

Future Research

At present, the capability of the available analytical imaging techniques are still limited to giving information on the physical and chemical state of the sample. Other information such as mechanical properties and state, both qualitatively and quantitatively, are also important. Increasing the amount of information that can be extracted from the analyses can prove to be useful in creating an ultimate analytical imaging technique.

Selected Publications

1) Jay Arre Toque and Ari Ide-Ektessabi, Investigation of the Degradation Mechanism and Discoloration of Traditional Japanese pigments by Multispectral Imaging, Proceedings of SPIE, Vol. 7869, 78690E, 2011.

2) Jay Arre Toque, Yusuke Murayama and Ari Ide-Ektessabi, Polarized Light Scanning for Cultural Heritage Investigation, Proceedings of SPIE, Vol. 7869, 78690N, 2011.

3) Jay Arre Toque, Masateru Komori, Yusuke Murayama and Ari Ide-Ektessabi. Analytical Imaging of Traditional Japanese Paintings using Multispectral Images. VISIGRAPP 2009, CCIS 68, pp. 119-132, 2010. Springer-Verlag Berlin Heidelberg 2010.

4) Jay Arre Toque, Yusuke Murayama and Ari Ide-Ektessabi. Pigment Identification based on Spectral Reflectance Reconstructed from RGB Images for Cultural Heritage Investigations. Proceedings of SPIE, Vol. 7531, 75310K, 2010.

5) Jay Arre Toque, Yuji Sakatoku and Ari Ide-Ektessabi. Analytical Imaging of Cultural Heritage Paintings using Digitally Archived Images. Proceedings of SPIE, Vol. 7531, 75310N, 2010.

6) Jay Arre Toque, Yuji Sakatoku and Ari Ide-Ektessabi, Pigment Identification by Analytical Imaging using Multispectral Images, Proceedings 2009 IEEE International Conference on Image Processing (ICIP '09), pp. 2861-2864, 2009.

7) Jay Arre Toque, Y. Sakatoku, Julia Anders, Yusuke Murayama and A. Ide-Ektessabi, Multispectral Imaging: the influence of lighting condition on spectral reflectance reconstruction and image stitching of traditional Japanese paintings, Proceedings of IMAGAPP 2009- International Conference on Imaging Theory and Applications, pp.13-20, 2009.

8) Jay Arre Toque, Y. Sakatoku, Julia Anders, Yusuke Murayama and A. Ide-Ektessabi, Analytical imaging of cultural heritage by synchrotron radiation and visible light-near infrared spectroscopy, Proceedings of IMAGAPP 2009- International Conference on Imaging Theory and Applications, pp.121-128, 2009.

9) Y. Sakatoku, Jay Arre Toque, and A. Ide-Ektessabi, Reconstruction of hyperspectral images based on regression analysis: optimum regression model and channel selection, Proceedings of IMAGAPP 2009- International Conference on Imaging Theory and Applications, pp.50-54, 2009.

10) Jay Arre Toque and Ari Ide-Ektessabi. Reconstruction of elemental distribution images from synchrotron radiation x-ray fluorescence. International Journal of Modern Physics B, Volume 23, No. 4, 557-569, 2009.