The Aims and Methods of Optical Analysis

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In Japan, cultural properties preservation standards require that all information gathering from cultural properties be done by non-destructive, non-invasive methods. Given the structurally delicate nature of paintings, it is not easy to preserve a painting's current state, even when the most careful handling is employed. While surveys of paintings are important for gathering various types of information about the work, all survey methods must be non-destructive, and undeniably such surveys raise issues that challenge the necessary preservation and conservation of the art work. We must avoid indiscriminate surveys that do not have cultural properties preservation as their basic premise.

The gathering of information conducted under the joint-study project detailed in this publication was carried out solely through digital recording methods, with the exception of the X-ray imagery taken by the Nara National Museum. The results garnered from this study were not intended simply to supplement past materials on the artwork, but rather the goal was to produce and publish new basic information that deepens our understanding of the facts about the painting.

Excluding limitations that occur in the printing and publication of materials, the framework of the digital medium is a response to the needs of our age. Also, given the present state of color display on monitors and the differences that occur in color management and color workspace, even though color monitors have finally appeared on the market that can duplicate the color quality of fine printing, prices are still high and these monitors are thus not yet readily available. Even displays with wide color range used in commercial settings are just being developed and standards are being set. Under the recently set xvYCC standard (IEC61966-2-4), the color spectrum has been expanded to display all colors within the visible range, and yet we are not yet at the stage where a monitor can reproduce all the colors that are present in printing.

Because the digital information gathered from this survey fully responds to the new standards through mathematical manipulation, image information will be publishable through digital media in the near future.

The following is a simple explanation of the methods used in this study, and we hope that readers will refer to this information along with the plates and explanatory texts as an aid to understanding the results of this survey.

Explanation of Methods Used

1) Color Images

The special physical properties of all types of matter respond to light with different reflective, refractive and permeation rates. Thus, by accurately illuminating small particles within an art work, tiny amounts of permeated colors are reflected, rich color spectrums are recreated visually, and a visual image is created that contributes to an understanding of the expressive methods used by the artist.

The determination of the direction and angle of the light rays involved must be based on an understanding of various factors, such as the materials and the size of their particles that make up the painting and the state of the work. Each individual painting is in its own complex and unique state, different from other paintings. As a result, methods that fit the work in question must be employed to correctly grasp the specific characteristics of the pigments and other materials used in the work. The surface reflective rate of a painting is influenced by the materials used in the painting's support media and the refraction rates of any materials adhering to that support media. As a result, the amount of light reflected by the recorded visual image varies in proportion to the rate of reflection. Plate 1 eliminates the color information and shows what can be verified by the differences in tone.

2) X-Ray Images

X-rays can be categorized by the length of their light rays, namely the 0.1 nm—10 nm range and the 0.001 nm—0.1 nm range. The X-ray images published in this book were taken at the Nara National Museum and used the 0.1 nm—10 nm X-ray range.

X-rays are frequently used in the examination of the structure of three-dimensional objects as a means of understanding the characteristics of the internal structure of a physical object. In the case of two dimensional works such as paintings, differences in materials and thicknesses result in different x-ray absorption, and this results in different tonalities that are recorded on a light-sensitive medium. The resulting visual image can be used to verify differences in the material nature of pigments used and the thickness of application.

To create an x-ray image, an x-ray sensitive medium is placed behind the object being examined. In the case of this painting, x-ray sensitive film was placed behind the painting and X-ray beams in the 0.1 nm—10 nm range were then projected at the front of the painting. X-rays in the 0.1 nm—10 nm range easily pass through the lighter element materials, and thus the amount of energy used increases and the visual image density heightens, i.e. the visual image darkens. Conversely, since it is harder for energy to pass through heavier elements, the energy is absorbed rather than transmitted. This results in lower visual image density and hence a lightening of the visual image.

Differences in the visual image density created by 0.1 nm—10 nm range x-rays not only shows differences in material structure, they also show disparities in thickness for specific areas of the same material.

Because the interpretation of a 0.1 nm—10 nm x-ray image is often based on the material makeup of an object, it is important to consider gathering overall results for a study object by combining x-ray-derived information with other forms of information sources, such as X-ray fluorescence analysis.

3) Near Infrared Imaging

Near infrared imaging is an image recording method that reproduces the differences in image tonal density relative to the object's reflection or absorption of near infrared light rays. Infrared radiation can be divided into three types, near infrared, mid infrared and far infrared. The images reproduced here were shot in the 800 to 1,100 nm range of the near infrared range (780 nm—2,500 nm).

The near infrared light range is characterized by an extremely high permeability rate. Thus, with the exception of an extremely limited wavelength range that is absorbed by moisture, the near infrared light range is not absorbed by the intervening matter and these rays can be captured on film. This characteristic of the infrared wave length is used to advantage in the gathering of information from cultural properties. Two variations of infrared imaging were used in this study, near infrared images lit from behind and near infrared images lit from the front of the study object. The study made use of the fact that the absorption rate is low in near infrared imagery lit from the front, which then reads as differences in the image density relative to the differences in the object's surface reflection rate. As seen in Plate 3, in near infrared imaging lit from the front, infrared light rays are reflected off the object's physical surface, and recorded as differences in image density based on the levels of reflected energy and absorbed energy. Each material's characteristic reflective properties are recorded as different reflective amounts.

While near infrared imagery is often used to make a painting's underdrawing visible, when mineral pigments are layered over underdrawing lines, the infrared energy is absorbed by the mineral pigments and the underdrawing lines are not revealed. For example, while the thickness of the application has some impact on results, when white pigment that includes a metallic component is layered on a surface it has an extremely high near infrared reflection rate and thus no information can be gained about what is beneath that surface layer. Although also affected by some color materials and wavelength ranges, in the majority of instances when organic pigments constitute the top layer of a painting, the near infrared light passes through the organic materials. This means that it is highly likely that information can be obtained about the lower layers of such paintings.

In near infrared imaging lit from behind, the light source is placed behind the support medium of a painting and the image density corresponds to the rate of absorption and reflection of the infrared light rays. In the case of paintings, it may appear that the painting materials closely adhere to the support medium, but that close adhesion is not consistent across the painting. Thus, a large amount of the near infrared waves permeate and a gap opens with the sheltering absorption material, thus creating a greater degree of variation within the image density. This method renders underdrawing lines as visible and generates other information not available through near infrared imagery lit from the front.

4) Photoluminescence Imagery

Photoluminescence imaging is a process whereby images are formed by using the special characteristics of materials that emit light known as photoluminescence when the material is subjected to certain limited wavelengths of excitation light.

The material emits specific light qualities depending on the wavelengths of light used. In existing methods where ultraviolet light is used as the excitation light, adhesives such as *nikawa* animal glue emit photoluminescence and hence researchers cannot obtain photoluminescent reaction from the painting's expressive materials. Thus it is necessary to select light wave lengths within the visible range (380 nm—780 nm) as the so-called visible field excitation light.

The visual image information garnered by this method can provide information on organic pigments whose colors have been changed by a variety of causes. In the case of inorganic pigments, the light action causes absorption of the excited energy, effectively sinking the resulting image into blackness. Thus, visual differentiation of material properties can be achieved by comparison of areas of the image created with inorganic pigments and areas created with organic pigments. Indirect results are obtained when the previous blackening effect is recorded in areas where there is an advanced degree of inorganic pigment flaking, and hence there are many instances where an effective image is obtained which visually clarifies the state of an object.

(translated by Martha J. McClintock)