Ultra-High Resolution Scanning of the Ishibashi Foundation Collection

SABIA Inc. + SHIMBATA Yasuhide

In 2010, the Bridgestone Museum of Art, the predecessor of the Artizon Museum, began the process of migrating images of works in our collection from positive film to digital images. Photographers who specialize in photographing fine art began to photograph the works with digital cameras. At the same time the museum used this opportunity to test the use of new types of equipment for recording images. One trial used scanning instead of film or digital cameras to capture high-resolution images. Since that beginning, Sabia Inc., which develops digital conservation solutions for works in museum collections, has run additional trials using high-resolution scanning. On September 19, 2014, Sabia used their equipment to scan three paintings from our collection: *The Toutain Farm at Honfleur* by Corot, *Still Life with Horse's Head* by Gauguin, and *Young Man Playing the Piano* by Caillebotte. These tests demonstrated that Sabia scanners can produce higher-resolution images than film or digital cameras. With the cooperation of Panasonic, these high-resolution images were unveiled to the public on Panasonic TOUGHPAD 4K tablets (20-inch) in one gallery as part of the Bridgestone's Willem de Kooning exhibition (October 8, 2014 to January 12, 2015).

Based on a thorough examination of the scanning results, the museum was confident that the images could be used for numerous purposes. Ultra-high-resolution scans of one hundred important paintings from the Ishibashi Foundation collection were then carried out using Sabia equipment at the Ishibashi Foundation Art Research Center between April 15 and 29, 2016. This initiative was a joint project of the Bridgestone Museum of Art, Ishibashi Foundation, and Sabia Inc. Professor Ari Ide-Ektessabi at the Advanced Imaging Technology Laboratory, Graduate School of Engineering, Kyoto University, supervised the project, which was implemented by Koji Okumura, Jay Arre Toque, Masaaki Taniguchi, Ryota Magara, Mie Kado, Youko Oki, and Seiya Aoi from Sabia Inc., and Yasuhide Shimbata from the Bridgestone Museum of Art.

Sabia Inc. was founded in 2007 to build on technology for high-resolution large-scale scanners for cultural assets developed at Kyoto University. A digital archive solution company that provides full support for archival and content digitization of artworks and cultural assets in Japan and overseas, Sabia uses the latest digital technologies, including display in 4K, for the preservation and transmission of cultural assets. On this occasion, the Sabia Art Scanner-X and the Sabia Art Scanner-H ultra-high-resolution large-scale scanners were used to scan at a resolution of 1000 dpi. Sabia Art Scanners, specially developed for scanning cultural assets, provide

Scanning with Frame

Item	Description
Number of objects	85
Raw data size (GB)	38.74 GB
Name of scanner	LIAM-X
Scanning resolution	228 dpi
Stitching overlap	~ 20 cm
Maximum scanning width per scan stroke	83 cm (7,500 pixels)
Maximum scanning length per scan stroke	200 cm (18,000 pixels)
Maximum object width that can be scanned	4.0 m
Maximum object length that can be scanned	2.0 m
Scanning technique	Low resolution symmetrical scanning
Object types	100 paintings from the Ishibashi Foundation collection

Ultra-High Resolution Scanning

Item	Description
Number of objects	104
Raw data size (GB)	1749.26 GB
Name of scanner	LIAM-H
Scanning resolution	1010 dpi
Stitching Overlap	~ 8cm
Maximum scanning width per scan stroke	18cm (7,300 pixels)
Maximum scanning length per scan stroke	210 cm (83,500 pixels)
Maximum object width that can be scanned	4.0 m
Maximum object length that can be scanned	2.0 m
Scanning technique	High resolution 1) scanning with symmetric visible lighting; 2) scanning with specular visible lighting; and 3) scanning with symmetric near infrared lighting
Object types	100 paintings from the Ishibashi Foundation collection

uniform lighting with high-intensity LEDs, for rapid contactless and non-destructive scanning that delivers accurate color reproduction and high dimensional precision. By adjusting the light source, it is even possible to reproduce textures, which cannot be done with photographs. The images produced by this ultra high-resolution technology can be 30K in case of large works and 50K in case of small or medium-sized works. Initially these images will be displayed in 4K; but as display technology improves, it will be possible to show these images in 8K or higher resolution as the necessary equipment becomes available on the market.[1]

This paper outlines the project procedure, and describes all elements of the project, including scanning method and sequence, image post-processing, sample scan results, and photos of the project implementation.

This initiative was a joint project of the Bridgestone Museum of Art, Ishibashi Foundation and Sabia Inc. It was supervised by Professor Ari Ide-Ektessabi at the Advanced Imaging Technology Laboratory, Graduate School of Engineering, Kyoto University, and carried out by Koji Okumura, Jay Arre Toque, Masaaki Taniguchi, Ryota Magara, Mie Kado, Youko Oki, and Seiya Aoi from Sabia Inc., and Yasuhide Shimbata from the Bridgestone Museum. One hundred major works from the collection, primarily important Western and modern Japanese paintings, were selected for scanning.

The selected works were divided into two categories. In the first category, the paintings were scanned within their frames at 200 dpi. This resolution was used to increase the depth of field to capture the 3D features of the frame. During the planning stage, it was agreed to scan the frames because the frames were also considered important. The other category was scanning at a resolution exceeding 1000 dpi. At this resolution, the primary objective was to capture details in the work. Images obtained at this high resolution could be used for creating content for display on 4K or 8K displays. In contrast to low resolution scanning of the paintings and their frames under symmetric lighting, the ultra-high resolution scanning was done in three scanning modes: (1) scanning with symmetric visible lighting; (2) scanning with specular visible lighting; and (3) scanning with symmetric near infrared lighting. Conventionally, these three scans are done separately, but on this occasion the symmetric visible light scanning and the symmetric near infrared light scanning were done simultaneously to make the scanning process more efficient. The scanning progressed smoothly and took only twelve days. Since two days were spent on preparation, testing, and calibration, the actual scanning was completed in ten days.

Notes
1. Ari Ide-Ektessabi, Jay Arre Toque, Yusuke Murayama, Pengchang Zhang, "A Large High Resolution Scanner for Cultural Heritage Assets," *Journal of the Imaging Society of Japan*, Vol. 51, Issue. 6, 2012, pp. 623–629; Ari Ide-Ektessabi, "High Resolution Scanner for Cultural Heritage Analysis: Recent Developments," *The Journal of the Institute of Image Information and Television Engineers*, Vol. 64, Issue 6, pp. 778–782, June 2010; Ari Ide-Ektessabi, "Development of a Total System for Digitizing, Analyzing, and Displaying of High Resolution Large Files of Digital Heritage," *The Journal of the Institute of Image Information and Television Engineers*, Vol. 61, Issue 11, pp. 1562–1566, 2007.

Project Procedure:

Ultra High Resolution Scanning Parameters

Scanner	LIAM-H	
Scanning resolution (dpi)	1010	
Calibration chart	IT8	
	Focus Level	Single	Dual
Color difference (dE)	7mm	1.36	1.38
	10mm	1.35	1.32
	15mm	1.32	1.33
	20mm	1.34	1.30
	25mm	1.34	1.32
	30mm	1.30	1.32
	35mm	1.31	1.37
	40mm	1.29	1.35
	45mm	1.31	1.35
	50mm	1.28	1.40
	55mm	1.29	1.35
	60mm	N.A.	1.42
Light source type	Nichia Visible/ CCS NIR	
Light source configuration	VIS:Dual, 2 lines per side; Single 4 lines on the home side///NIR: Dual 2 lines per side	
Light source current (A)	VIS=2.0/ NIR=0.86	
Light source voltage (V)	VIS=19.7/ NIR=22.9	
Light source angle	VIS=50°; NIR=60°	
Camera	VIS=TLC-7300UCL/ NIR=TLC-7300UCL	
Controller and PC	3 Axis Gray box/ Dell Precision Tower5810	
Filter	VIS=UV/IR cut: NIR=IR76	
Lens	VIS=Apo Rodagon 105mm/ NIR=Apo Rodagon 105mm	
Lens aperture	VIS=8/ NIR=8	
Extension tubes	VIS=40+24; NIR=40+24	
Working Distance (cm)	50.7 (48.3+2.8) 100 on scale @7mm/0.486mLaser	
Distance of object to light source (cm)	VIS=9.5cm; NIR=8.5cm @35mm	

Low Resolution Scanning Parameters

| Name of scanner	LIAM-X
Scanning resolution (dpi)	228dpi
Calibration chart	IT8 Chart (v.R120804)
Color difference (dE)	1.68
Light source type	amano
Light source configuration	synmetric 8line
Light source current (A)	3.1
Light source voltage (V)	12.9
Light source angle	45°
Camera	takenaka7500 No.0366
Controller and PC	2axis controller, sabia Optiplex7010
Filter	IR/UV cut
Lens	Apo-60
Lens aperture	8
Extension tubes	none
Working Distance (cm)	93.8
Distance of object to light source (cm)	19cm,23cm

Schematic Diagram:
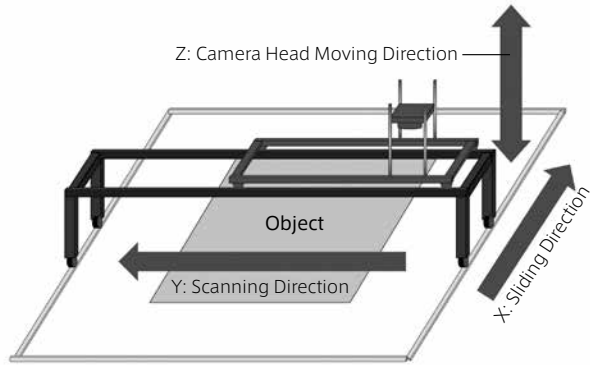
Figure 1: The scanner moves in three directions: Y is the scanning direction in which the camera head is moved over the object. X is the sliding direction of the scanner on the rails. Z is the camera head axis for adjusting the distance to the object to ensure optimum focus per scan.
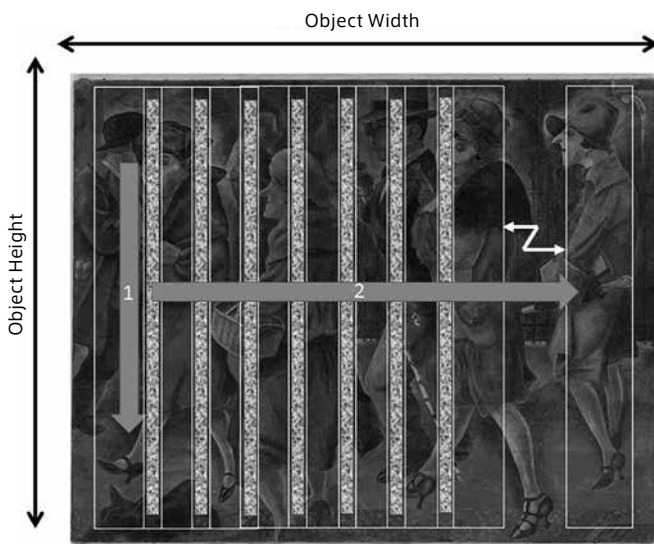
Scanning Sequence:

Figure 2: This image shows the general scanning sequence for the object. For this project, the maximum scannable object size is approximately 2 m × 1 m. The scanner frame slides along the Y-axis providing a minimum of 8 cm stitching width for the 1000 dpi scan and 20 cm for the 200dpi scan.

Image Processing Sequence:

Post-Processing and Color Calibration Procedure
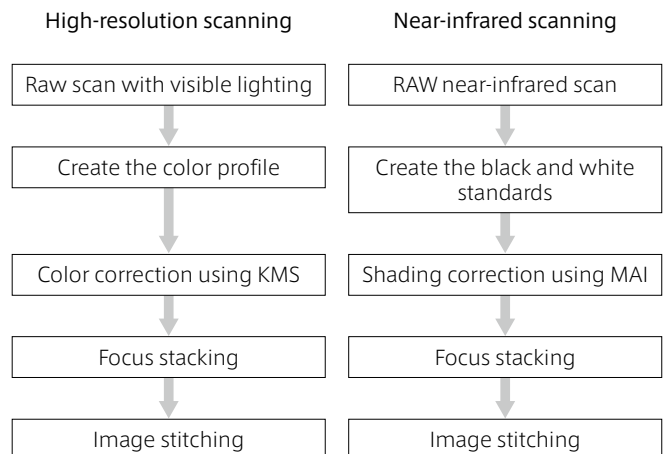
Figure 3: Data processing flow starting with raw data. All the images are obtained in uncompressed tiff files without optional color processing. Three types of images are obtained: symmetric lighting scans, specular lighting scans, and near infrared symmetric lighting scans. There are three types of images and two modes of image processing. The symmetric and specular scans are processed together, while the near infrared scans are processed separately. IT8 chart calibration data is used to generate a color profile for color images KMS (Color Management System) is then used with that profile to produce the gamma-corrected data. Since color does not exist beyond the visible spectrum, near-infrared image post-processing requires only shading correction to correct unevenness in the light distribution. After color management of the color images and shading correction of the near-infrared images, focus stacking of objects that were scanned at multiple levels was performed prior to stitching. Other images were stitched after color processing and shading correction.
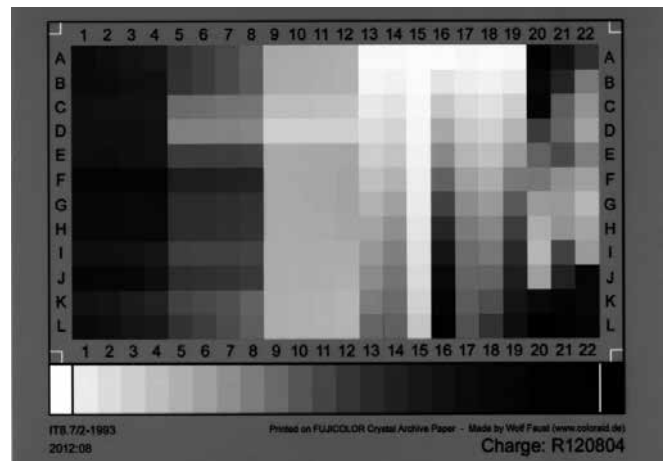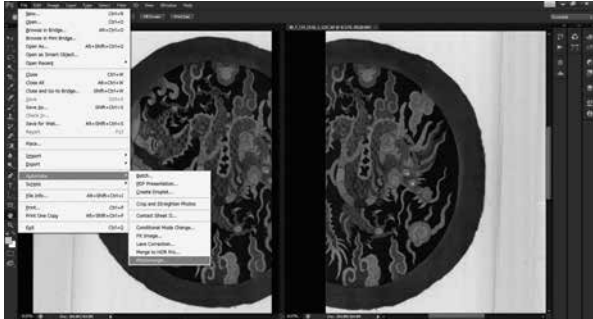

Figure 4: IT8 color chart used for color calibration

Image Stitching:

The images are stitched using the Photomerge function in Photoshop. The following sequence of images shows the general procedure used for stitching the images in this project. There are seven basic steps.

1. Open Photoshop→File→ Automate→Photomerge [Figure 5]

2. (1) Select Auto from Layout. (2) Press Add Open Files to select files for stitching. (Note: To maximize PC performance, stitch two to three layers at a time rather than the whole image at once.) (3) Deselect Blend Images. (Note: To prevent changes to the color of the Photoshop image). (4) Click "OK." [Figure 6]
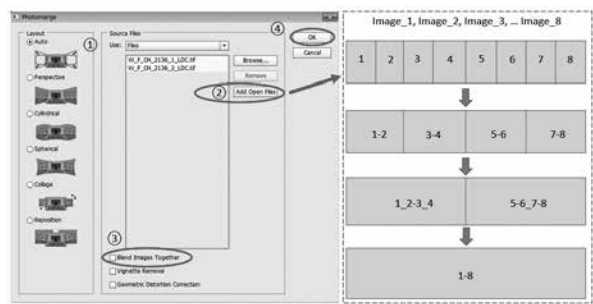
3. The image is aligned in the preceding procedure. The next procedure initiates the actual stitching process
(1) Go to the Layers window and select the layers that need stitching; (2) Select Auto-Blend Layers from the Edit dropdown menu [Figure 7]
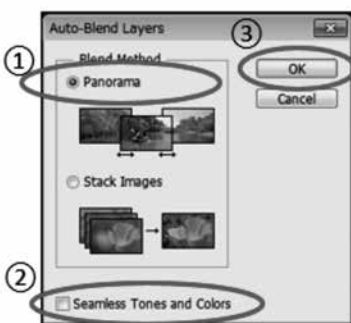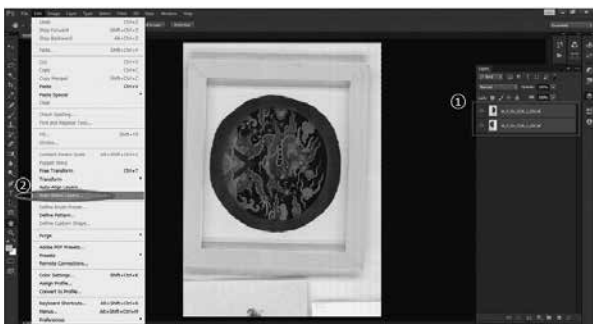
4. The Auto-Blend Layer window will pop out.
(1) Select Panorama.
(2) Deselect Seamless Tones and Color (Note: To prevent Photoshop from changing the color of the image.
(3) Click "OK."
[Figure 8]

5. Once the process has been completed, check the image. Use Photoshop to make minor adjustments as necessary. [Figure 9]

6. After the checks, use the Flatten Image function to stitch the image. [Figure 10]
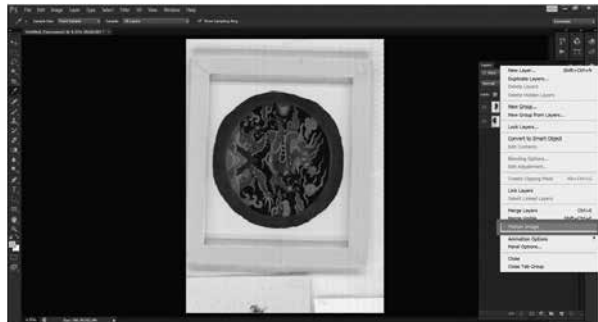
7. Save the images in the desired format. For images less than 4GB, tiff is the default format. For images larger than 4GB, the default is PSB. (Note: There is also an option to save intermediate data with layers. These images may be helpful in case of problems with the stitched images. It is therefore good practice to save all the processing data if there is space available on the storage disk.) [Figure 11]
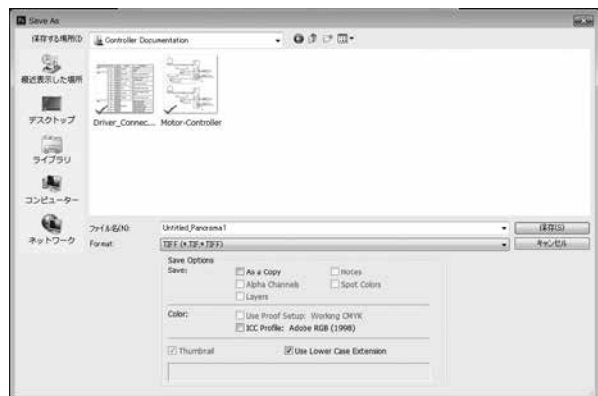
Results:

Visible (VIS) vs. Near-Infrared Scanning (NIR)

Object:
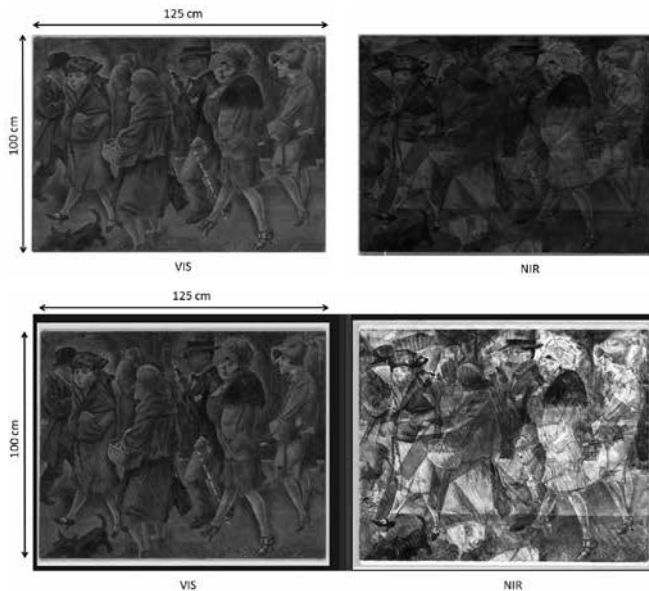George Grosz, *Promenade*
1926
Oil on canvas
100.3×125.7cm

Figure 12: This is a side-by-side comparison of visible light scanning and near infrared light scanning. As mentioned earlier, these images were obtained simultaneously. The ones on the left are visible light images and the ones on the right are near-infrared (NIR) images. There are two versions of the NIR image. The upper image is the original with only shading correction. The brightness and contrast of the lower image were increased to make it easier to see the detected features.
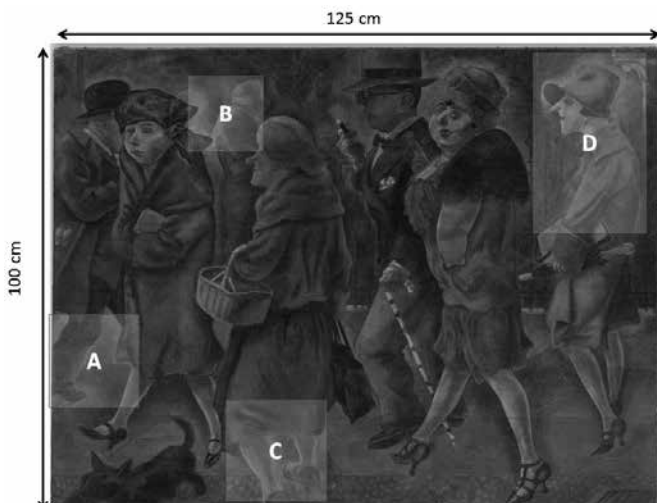
Figure 13: The image shows some areas of the painting where there is clearly another image below the top layer.
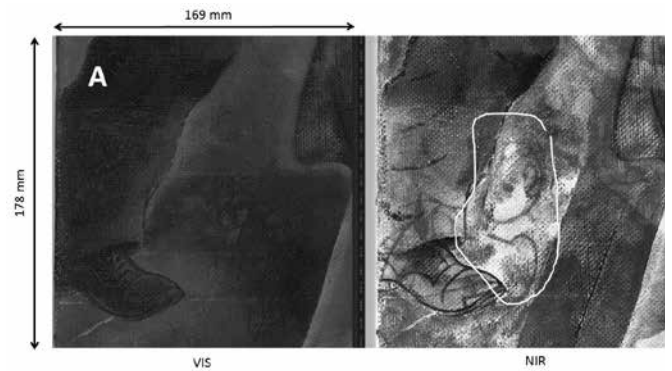
Figure 14: Area A shows something that cannot be identified above the shoe of the man in the painting. The NIR image reveals the image in much clearer detail.
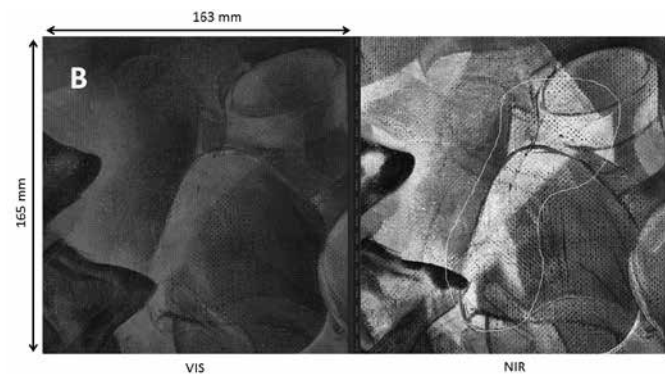

Figure 15: In Area B, the NIR scan shows a hand reaching into the bag of the lady in the painting. The VIS image shows a faint silhouette.
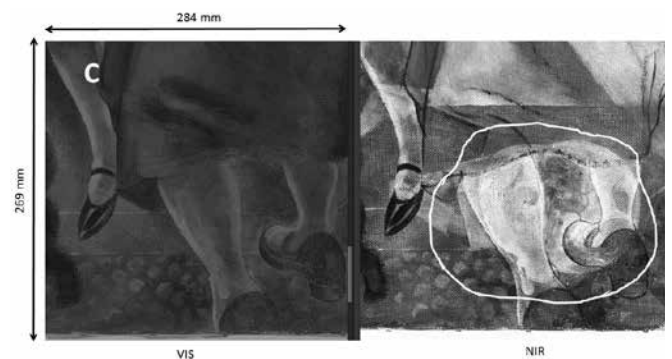

Figure 16: In Area C, there is large circle underneath the feet of the elderly woman in the painting.
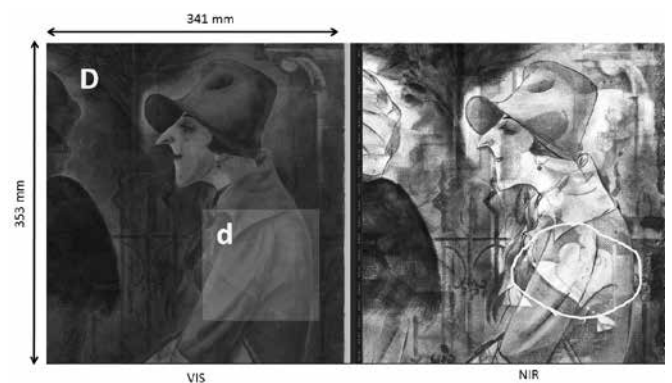

Figure 17: The image above clearly shows the most interesting image detected with NIR. It is the head of a man in a horizontal position and wearing a hat.
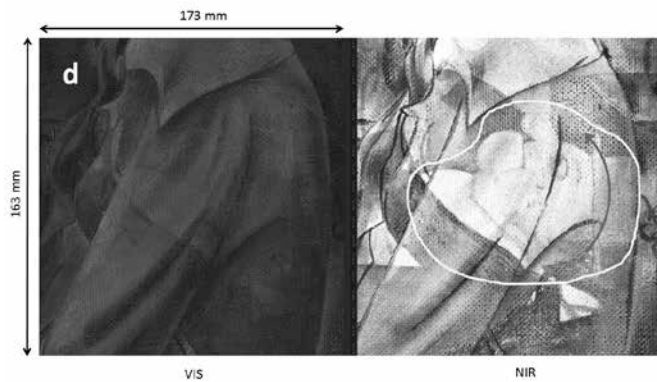
Figure 18: The image above shows a clearer view of the image detected in Figure 17. The man's head is painted at a 90 degree angle away from the orientation of the painting.
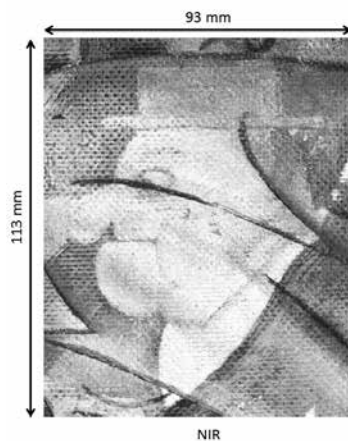

Figure 19: This is an enlarged view of the previous image. To get a clear view of the image discovered beneath the original painting, the painting was rotated counterclockwise by 90 degrees.

These are a few examples of images detected by the NIR scan that could not be seen on a VIS scan. Further investigation of the painting may yield more interesting discoveries.

Symmetric vs. specular scanning

This is a side-by-side comparison of two different visible light scans. The images on the left are scanned with symmetric visible lighting while the one on the right are scanned with specular visible lighting.

Symmetric Visible Lighting   Specular Visible Lighting

Symmetric Visible Lighting   Specular Visible Lighting

Figures 20 & 21: This is a comparison of symmetric and specular light scans. The images appear different because of differences in the ways in which incident light is reflected by the 3D texture of the image on the canvas.

Symmetric Visible Lighting   Specular Visible Lighting

Symmetric Visible Lighting   Specular Visible Lighting
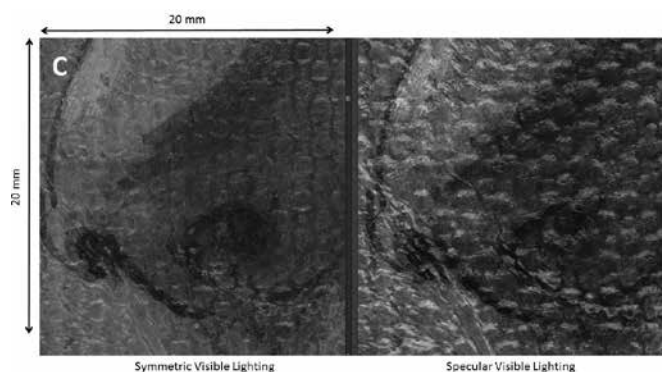
Figures 22 & 23: The images show a comparison of symmetric and specular light scans. The incident light is reflected by the 3D texture of the image on the canvas. With symmetric lighting, the shadow cast by the light from above and the shadow of the light from below cancel each other out. With specular lighting, the surface

texture is highlighted. Since the surface of this work is a little shiny, specular highlights are visible across the entire painting as well as at points that reflect the light along the camera axis.
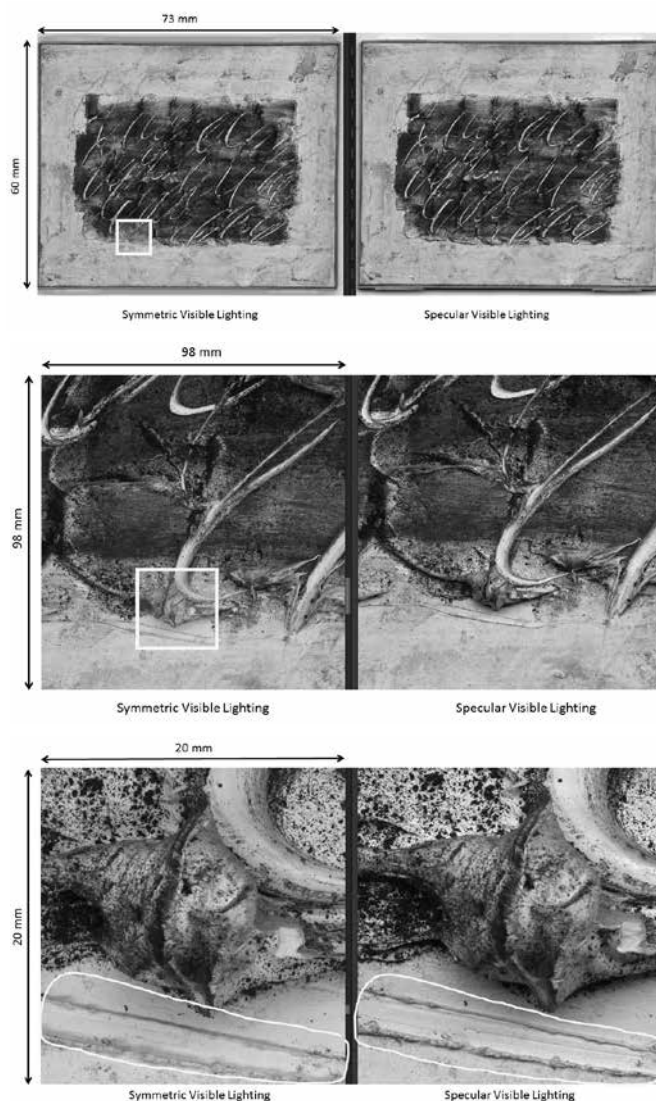
Object:
Jean Fautrier, *Circle line*

1963
Oil and paper pasted on canvas
59.9×73.1cm

Figures 24–26: These images were selected as one of the case studies for this report. These images are not glossy, but they are closer to 3D. Unlike the previous image, there are no blown-out highlights. The effect of the specular lighting is apparent from the shadows in the area circled in yellow.

Image Focus Stacking

The scans were done at a high resolution of about 1000 dpi. At this resolution, the focus depth is extremely shallow (<1 mm). It was necessary to perform focus stacking scans to produce an image with good focus across the whole object, due to the unevenness of the object's surface. Figure 27 is a schematic representation of how focus stacking was used in this project.
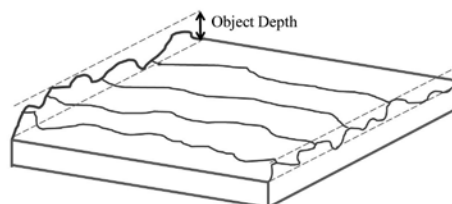
Object Depth = the distance between the lowest point to the highest point on the object surface

Focus depth = combined depth of focus with respect to different focusing plane

For a good scan image:

Focus depth > Object Depth

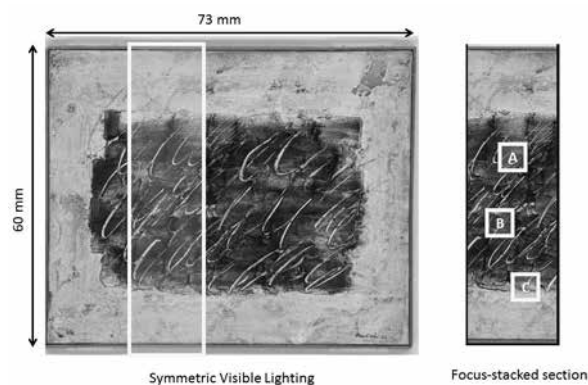Figure 27: Focus stacking

Figure 28: This painting required focus stacking. The three marked areas were selected for closeups.
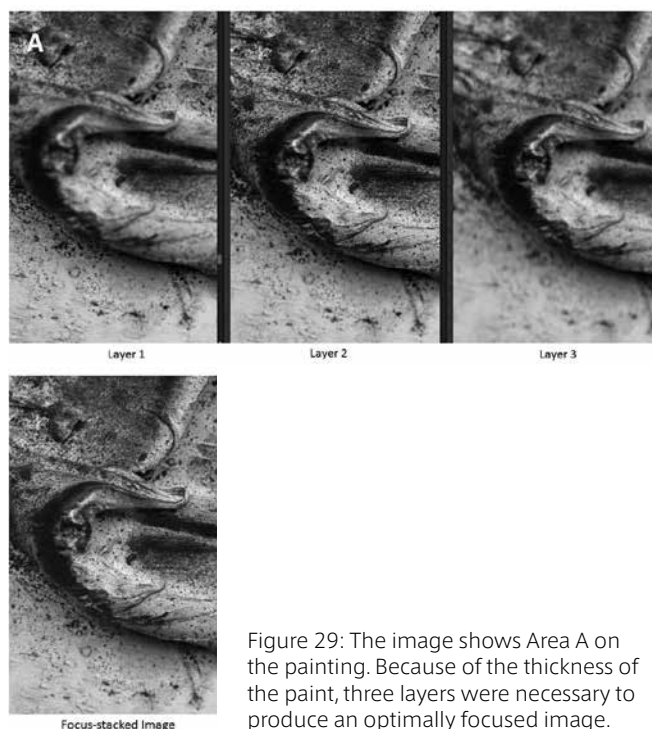

Figure 29: The image shows Area A on the painting. Because of the thickness of the paint, three layers were necessary to produce an optimally focused image.
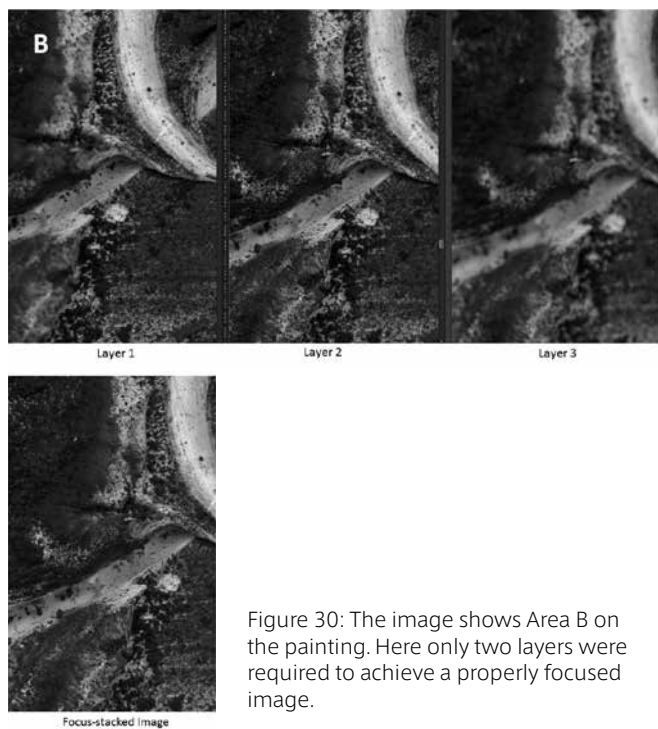
Layer 1　Layer 2　Layer 3

Focus-stacked Image

Figure 30: The image shows Area B on the painting. Here only two layers were required to achieve a properly focused image.

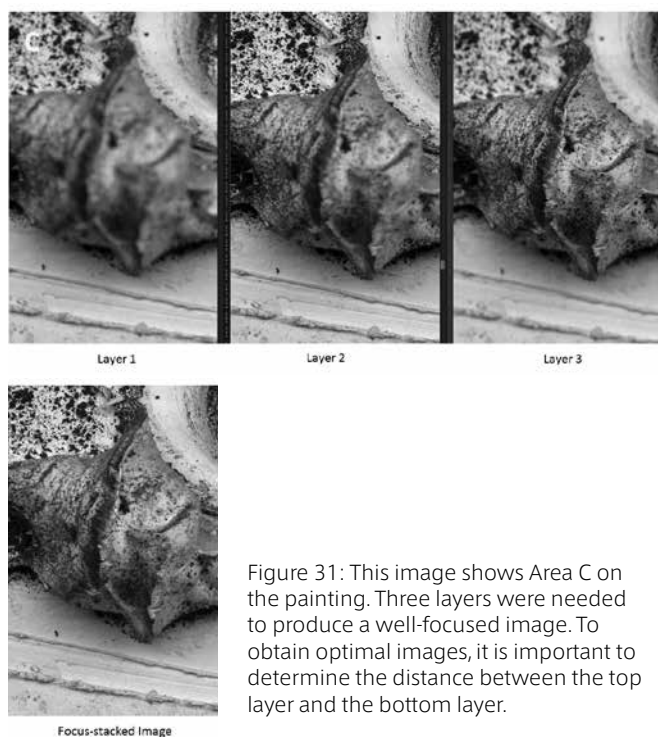
Layer 1　Layer 2　Layer 3

Focus-stacked Image

Figure 31: This image shows Area C on the painting. Three layers were needed to produce a well-focused image. To obtain optimal images, it is important to determine the distance between the top layer and the bottom layer.

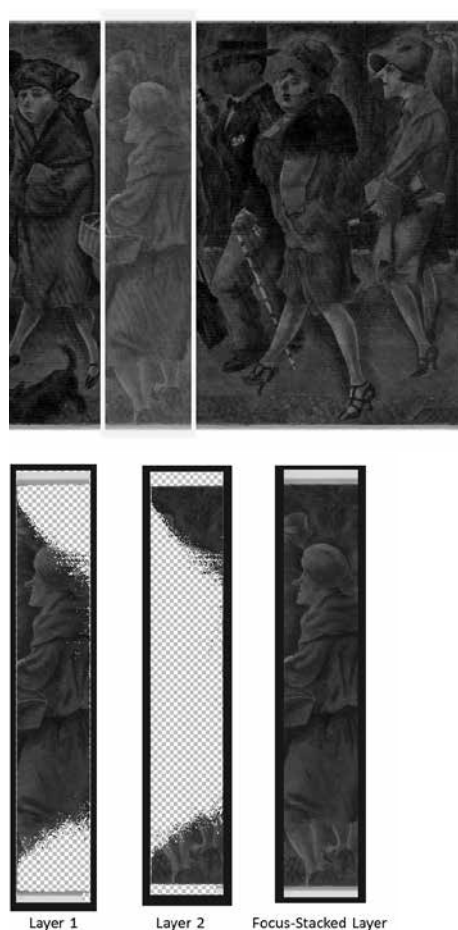

Layer 1　Layer 2　Focus-Stacked Layer

Figure 32: The image above is the second example selected to demonstrate focus stacking. In this case, only two layers were used because the painting is almost flat. The main issue here is that the canvas is sagging. Since the paintings are scanned in a horizontal position, the weight of the canvas tends to cause the painting to sag in the center, especially in the case of large paintings. If the canvas is properly stretched, this phenomenon can be minimized. But focus stacking becomes necessary with old paintings that tend to sag more easily.

Conclusion

The images obtained by high-resolution scanning of approximately 100 important paintings from the Ishibashi Foundation collection include modern Western paintings, modern Japanese-style paintings, and Japanese antiquities from the main collection. The results obtained are high-resolution images compatible with at least 30K for large works, and 50K for small or medium-sized works. Initially, the material will be displayed on 4K equipment, but it will be possible to use these images on equipment with 16K or even higher image quality in the near future when such equipment becomes available on the market.

The images obtained at this time will be used for a variety of purposes. To begin with, as a record of the condition of the works, they will be used for conservation management and to record how works change as they age. The scanned images, including the infrared images obtained during the high-resolution scanning, will be linked to the existing database to support a variety of applications.

The images have already been used on several occasions. After the closure of the Bridgestone Museum of Art in 2015, the works were moved to the Ishibashi Foundation Art Research Center in Machida, which was completed in 2016, where they will be stored until the opening of the new museum. At the time of the removal, the images were used to examine the condition of the works. Meanwhile, when the Ishibashi Foundation lent approximately seventy works from its collection to the Musée de l'Orangerie in Paris for the *Tokyo-Paris Masterpieces from Bridgestone Museum of Art, Collection Ishibashi Foundation exhibition* (April 5 to August 21, 2017), the images were extensively used to examine the condition of the works (Figure 33).[2] At the time of the Paris exhibition, the high-resolution images were consulted to examine the condition of the works when they left the ARC, when they were shown at

the museum in Paris, when they were removed, and when they were returned to the ARC after being transported back to Japan. For better accuracy when producing the reports, the images captured with the high-resolution scanner were used to confirm details by viewing them on a 4K tablet as well as with the naked eye.

This project was also presented to researchers, restorers, and museum staff mainly in the United States at the 46th Annual Meeting of the American Institution for Conservation of Historic and Artistic Works held at the Marriott Marquis Houston in Houston, Texas, from May 29 to June 2, 2018 (Figures 34 & 35).[3]

(Translated by Ruth S. McCreery, The Word Works, Ltd.)

Notes

2. *Paris/Tokyo: Chefs-d'œuvre du Bridgestone Museum of Art, Collection Ishibashi Foundation, Musée de l'Orangerie*, Paris, 5 avril–21 août, 2017.
3. *Material Matters*, AIC (American Institution for Conservation of Historic and Artistic Works), 46th Annual Meeting in Houston, at Marriott Marquis Houston, May 29–June 2, 2018, Program, p. 116.

Figure 33

Figure 34

Figure 35