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Post Processing of Reflectance Transform Imaging for Isolation of Surface Impressions

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Abstract

An important aspect in paper conservation is identification of the source of a paper used for a work of art. Identifying three-dimensional characteristics such as laid lines, chain lines, and watermarks made in the manufacturing process of papers can aid in this process. Reflectance Transform Imaging (RTI) has become a point of interest[1], as it is particularly useful when the primary support is lined with secondary or even tertiary supports of canvas, boards, or other papers with different textures that would obstruct the use of transmitted light or X-ray imaging. Working with the surface normal and depth map generated from a 3D model based on the RTI data, we use frequency separation methods and Fast Fourier Transforms to isolate specific three-dimensional features from the images.

Overview

The Yale Center for British Art is undertaking the study of a group of large-scale preparatory watercolors by Samuel Scott (ca. 1702–1772, British) in their collection. The primary supports of these watercolors are antique laid paper bearing watermarks, which are lined with one or two layers of textured canvas and other types of laid papers and paste for lining. There are noticeable distortions and creases in the paper support caused by prolonged usage of the artwork, as well as by the uneven and rough application of paste. In initial testing, light was unable to penetrate the triple-layered structure of the objects. Thus, conventional transmitted light imaging was ruled out. X-ray imaging also proved ineffective in recording the watermarks on the primary support, as the higher density secondary and tertiary supports completely obscured these features and the images were dominated by the canvas lining material [fig. 1].

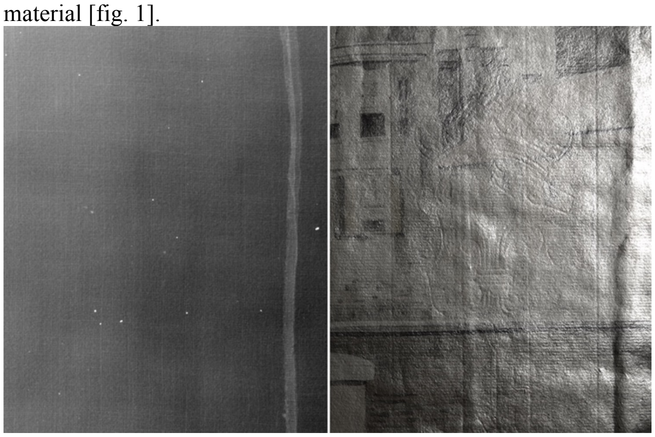

***Figure 1**. Canvas backing completely obscures watermark in X-ray (left). The CHI RTI viewer reveals impression in the same region (right).*

Reflectance Transform Imaging (RTI) has been investigated as a method for viewing watermarks by adjusting lighting angles. The Cultural Heritage Imaging RTI viewer (the CHI viewer)[2] provides a specular enhancement feature which helps accentuate the surface impressions further when choosing a raking angle for the light. Raking light may be insufficient to decipher certain complex features. Although surface impressions like the watermarks, laid lines, and chain lines are exaggerated, the effect is augmented for features running perpendicular to the light source. Thus, one must choose an angle of light that will best highlight most of the lines in question, often requiring a compromise that may not highlight all of the desired impressions. Furthermore, other surface distortions and undulations that distract from the reading of the impression are exaggerated. There are also cases where the artwork itself can become a distraction and obscure the impressions. Here we describe two approaches we attempted to overcome in order to isolate the desired surface impressions.

Surface Normals

The CHI viewer offers a surface normal viewing mode that mitigates many of these problems as it provides a representation of the surface geometry. The surface normal map provides the normal vectors of the object's surface at a given point separating the X, Y, and Z values of the vectors into Red, Green, and Blue color channels [fig. 2]. While this method does present as much data as possible, it is typically not immediately legible. For this use case the primary interest is impressions, identified by steep angles and where those angle changes rapidly.

One limitation of the CHI viewer is that it does not allow a full resolution export of the surface normal map; instead it only allows for screenshotting of the current monitor view. To obtain a high resolution surface normal map for processing, several screenshots may be taken with zoom at 100% and stitched together using automated stitching software such as Adobe Photoshop's photomerge feature to reposition and blend the views into a high resolution composite.

The Z value of the surface normal typically provides very little information and for the most part is equal to 1 (255 in 8-bit notation). Thus, for the purposes of this processing, the Z channel is ignored. The X and Y values are range from 0 to 1 (0-255). While the exact angle in two dimensions is useful in other contexts, for this application we were only concerned about the overall slope and specifically rapid changes in slope.

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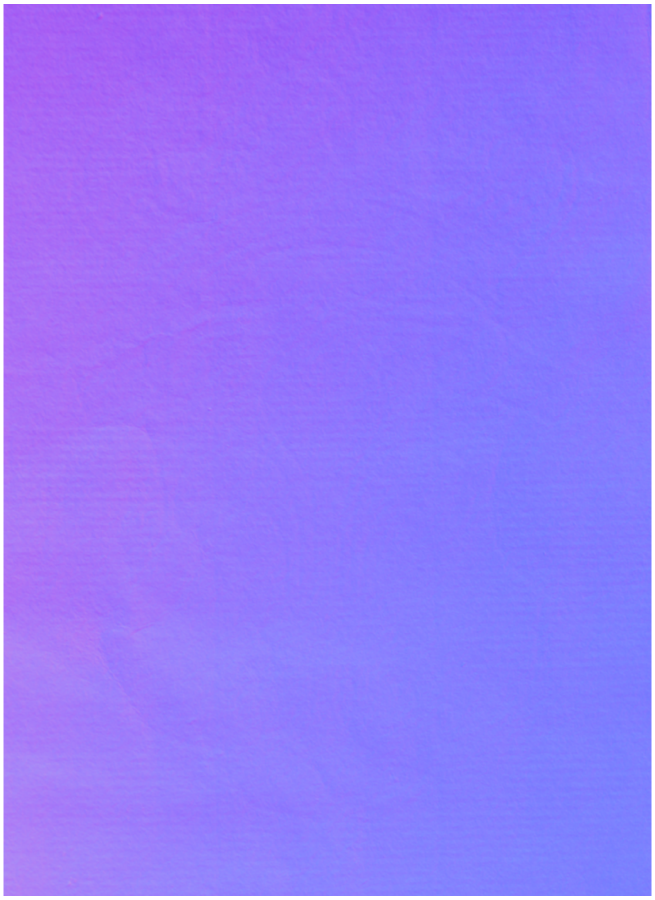

***Figure 2**. Surface normal map of watermark.*

The magnitude of the angles can be approximated by applying a hard "V" shaped curve [fig. 3] to each channel so that extreme angles with values of 0 or 255 will have an output of 255 and a normal in line with the viewer will have value of 127 would have an output of 0. These results for the Red and Green channels can then be added together to form a single greyscale image. It is worth noting that none of our initial images have had angles greater than 45º, and thus, there was no issue with clipping when adding the channels. If this is a concern, processing the individual channels with a curve that had a lower maximum output would prevent clipping.

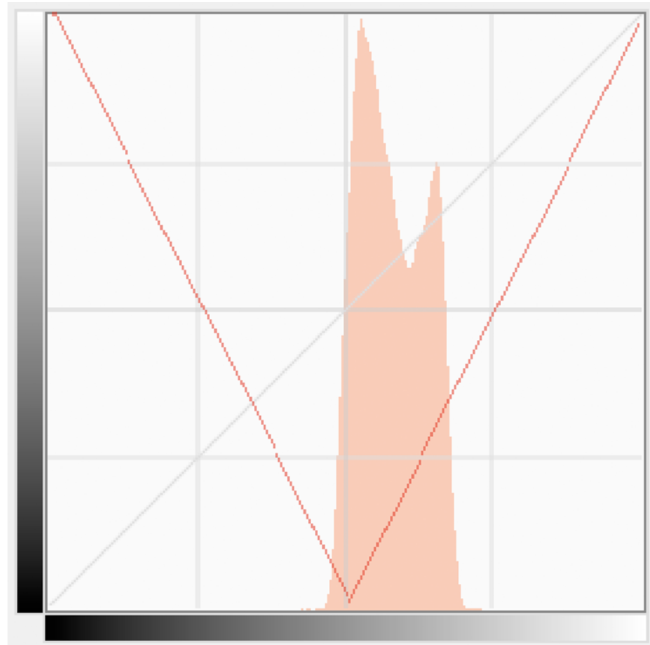

***Figure 3**. A V shaped curve renders normals perpendicular to the viewer as black and lighter the more they deviate from perpendicular.*

This process results in greyscale image that identifies the magnitude of the slope at any given point [fig. 4]. While the impressions are made more visible, the distortions and undulations of the paper are also exaggerated. One other problem apparent in this image stems from a known issue with current RTI processing where the software assumes the light source is infinitely far away. That assumption causes a warping in the shape of the rendering (often referred to as "potato-chipping," after the shape the warping takes)[3]. This results in the magnitude of the slope near the edges being significantly higher than that near the center of the image. Figures 2, 4, and 5 represent detail from the upper right corner of a larger RTI image. The top left of the detail is closer to the corner of the area imaged and shows more warping compared to the bottom right corner of the detail which is closer to the center of the imaging area.

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***Figure 4**. Display of deviation of surface normal from perpendicular.*

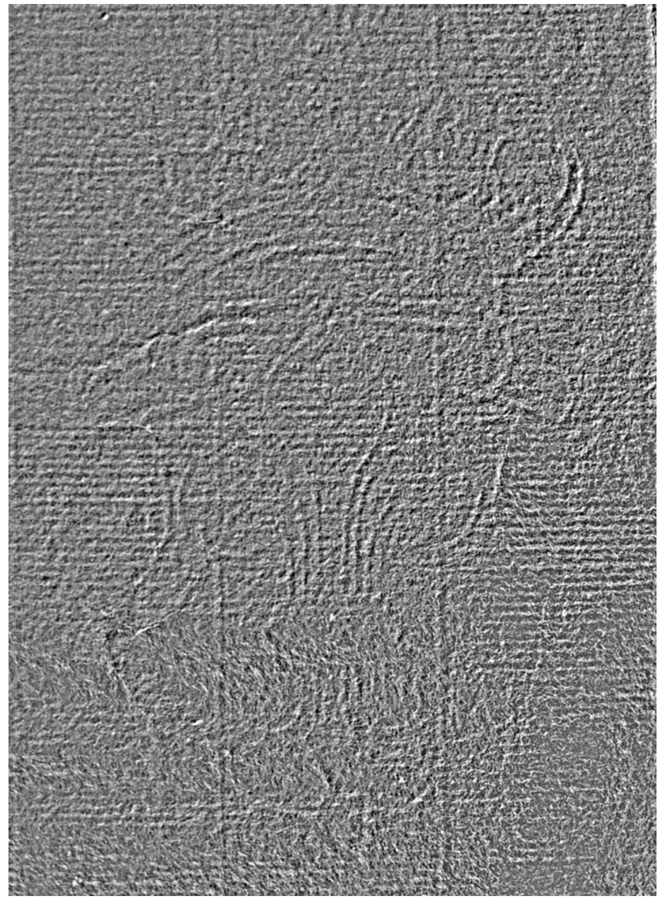

***Figure 5**. Gaussian Blurred copy applied to original via subtraction blending (contrast increased for legibility).*

These distracting distortions in the support and the warping of the surface normal map can be characterized as low frequency changes, while the surface impressions we wish to isolate tend to be high frequency changes. If the support distortions and “potato chipping” inherent in the RTI process are undesirable, a simple high pass filter can be used to eliminate low frequency features and leaves only the high frequency ones. We found that applying a Gaussian blur to a copy of the image and subtracting it from the original produced a more legible image [fig. 5] than a traditional high pass filter. The pixel radius of the blur was determined by measuring the width of the transition in the areas of the impression; however, this could be done more qualitatively by adjusting while looking at the preview.

The watermark, laid lines, and chain lines are typically viewed together for identification. However occasionally the laid lines can be distracting and make it difficult to interpret the watermark if the impressions are weak. In this case, the processed image can then be processed with a Fast Fourier Transform (FFT) using ImageJ, creating a frequency domain image. Because the laid lines are typically a regularly periodic pattern they will show up as 2 bright points in the frequency domain [fig. 6]. Masking these areas out and using an inverse FFT thus creates an image with the pattern of laid lines removed. If it is desirable to isolate the laid lines, this image could be subtracted from the previous processed image. The chain lines are less regular and proved more difficult to remove without negatively impacting the appearance of the watermark.

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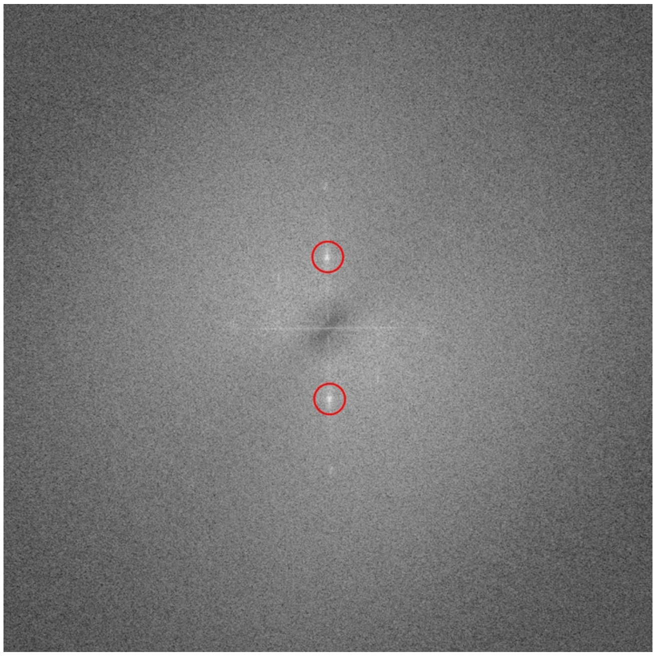

***Figure 6**. Peaks in the frequency domain image highlighted in red.*

Although the surface normal approach does provide an image that highlights surface impressions, there are several artifacts that can cause it to be less legible than desired. As the surface normal image often depicts shallow angles and with the normal map recorded as 8-bit values, precision errors tend to create very noisy results. If the gloss of the surface varies (such as a metallic paint or glossy ink on a matte support), the surface normal map may inaccurately depict this variation as having a steeper normal [4], introducing more artifacts into the surface normal rendering. Thus, portions of the artwork may show through in the surface normal.

3D Depth Map

To bypass some of these issues, we developed a secondary approach where a 3D model was created from the RTI captures using a program developed by the Department of Computer Science at Yale University [5,6]. This model allowed us to view the object as a depth map image [fig. 7] where the brightness of a pixel is determined by its distance from the viewer. Although, this method also suffered from distortions in the support medium and the "potato-chipping," high pass filtering and increasing contrast created a clearer image than the surface normal. When increasing the contrast, we opted to invert the brightness so that the depressed areas are white and the rest of the surface is darker creates an appearance that is reminiscent of transmitted light photography where the thinner areas of support will appear lighter, making this process useful in comparing with transmitted light photographs of other watermarks [fig. 8]. As with the surface normal image, FFT processing can also be done on this image if the laid lines are not desired [fig. 9].

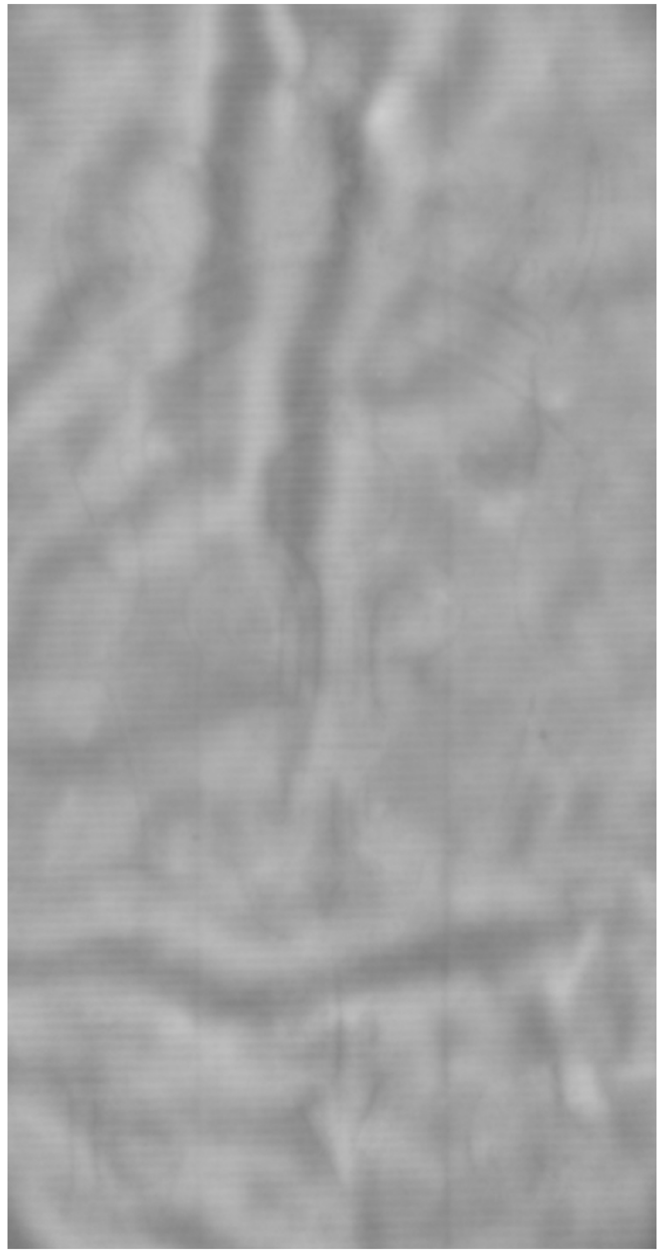

***Figure 7**. 2D Depth map rendering of 3D model.*

A problem encountered with the 3D model method is that while the 3D program does record a pixel dimension to scale to the real world object, when going from a 3D model to a 2D depth map, some programs may lose these values. Furthermore, to reduce errors, the model is only built of the region of interest in the RTI capture and not the entire capture. This means the 3D model will not include rulers or measurement scales that were present in the original capture. In the event scale is lost during processing, one can use the surface normal processing which includes a ruler as a reference for the scaling of the image processed from the depth map. To test that the scaling was maintained, both the surface normal and depth map images were printed on transparencies and compared to the original surface impression. The transparencies and the original visually matched.

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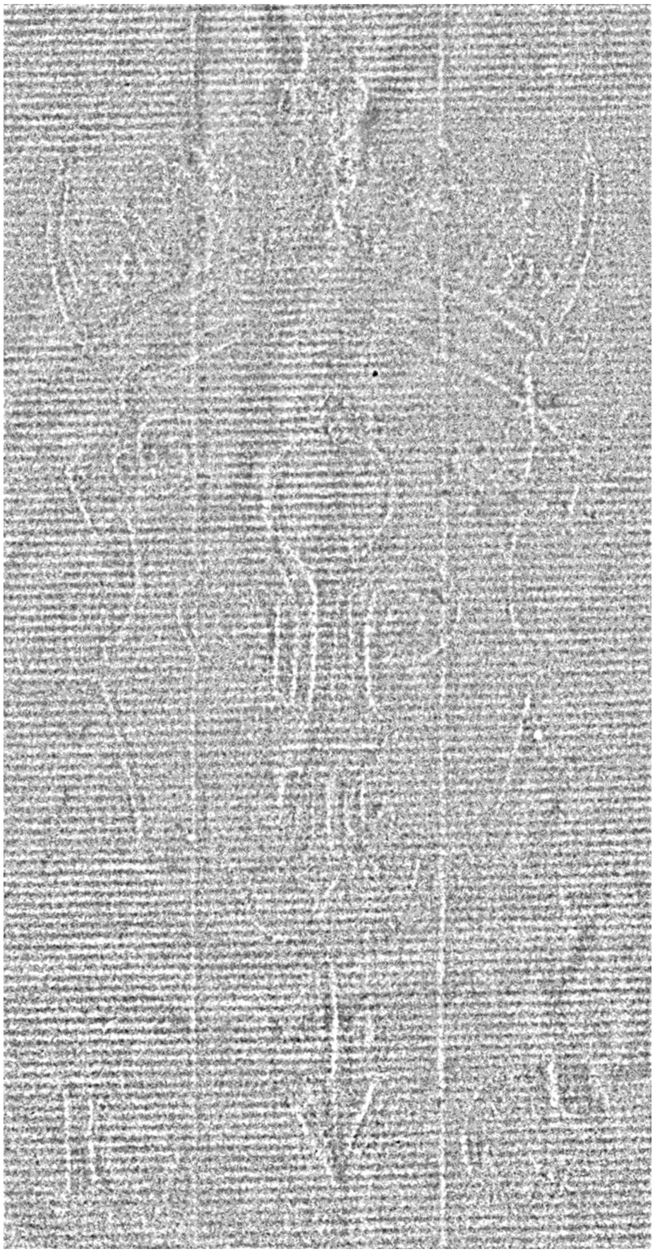

Figure 8. *High Pass filter on depth map (contrast increased and tone inverted) to isolate high frequency features.*

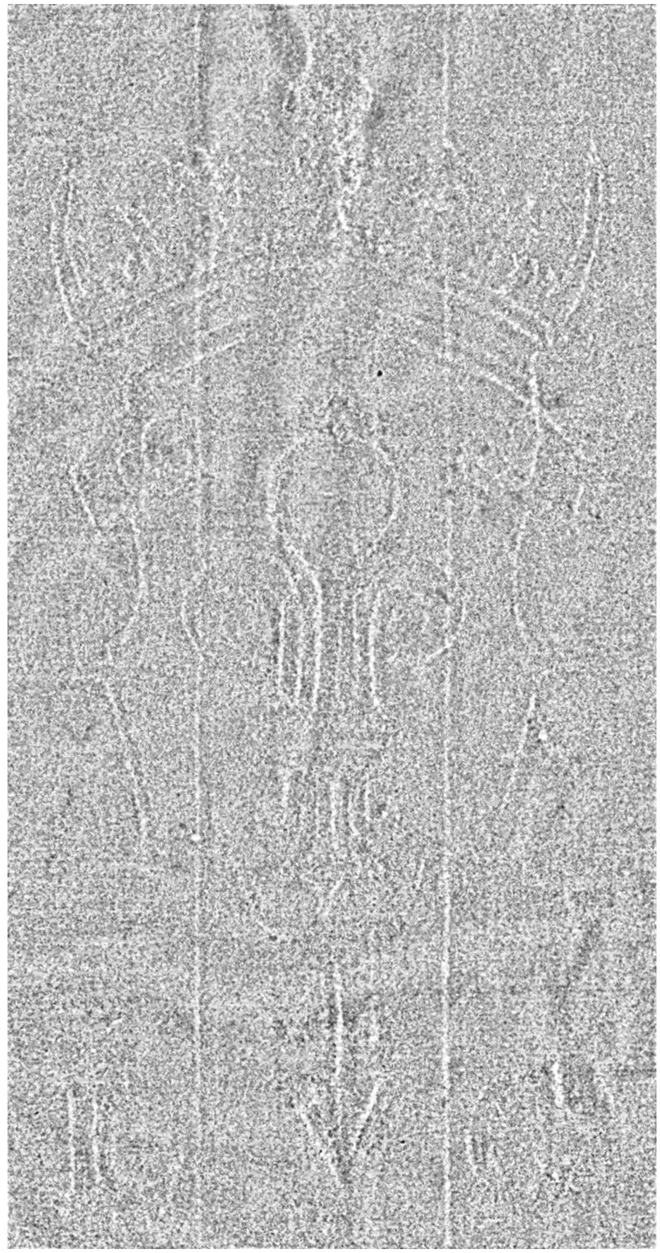

Figure 9. *Laid lines removed using Fast Fourier Transform.*

While these processes are imperfect and do have some limitations, they can be useful to create images that emulate the appearance of transmitted light when such imaging is impossible. We hope that these types of techniques might prove useful for adding images to databases of watermarks and surface impressions that are comprised primarily of transmitted light photographs or X-ray images.

References

[1] Manfredi, Marco, Greg Williamson, Dale Kronkright, Eric Doehne, Michael Jacobs, Emilio Marengo, and Gregory Bearman. "Measuring changes in cultural heritage objects with Reflectance Transformation Imaging." In *Digital Heritage Int. Congr. (DigitalHeritage), 2013*, vol. 1, pp. 189-192. IEEE, 2013.

[2] Cultural Heritiage Imaging, *Reflectance Transform Imaging*, [Online]. Available: http://culturalheritageimaging.org/Technologies/RTI/

[3] George Dietz, *Arbeitsanleitung zur Isolation von Papierstrukturen und Wasserzeichen aus Zeichnungen und Graphiken mittels Bildsubtraktion,* [Online]. Available:

http://www.papierstruktur.de/wp-content/uploads/Bildsub_gesamt_2013.pdf

[4] MacDonald, Lindsay W. "Colour and directionality in surface reflectance." In *Proc. Conf. on Artificial Intell. and the Simulation of Behaviour (AISB)*. 2014.

[5] R. Pintus, S. Podda, F. Mighela, and M. Vanzi.. "Quantitative 3D reconstruction from BS imaging." Microelectronics Reliability 44, 1547 (2004).

[6] Jason DeBlock, Richard House, Elena Torok, and Scott Williams, *Cross-Departmental Collaboration Using 3D Technologies at Yale* (MCN, Dallas, TX, 2014).

Author Biography

Kurt Heumiller received a Bachelor of Fine Arts in Professional Photographic Illustration with a minor in Imaging Systems Management from the Rochester Institute of Technology. Since 2008 he has worked as the Senior Imaging Systems Specialist at the Yale Center for British Art in New Haven.

Jens Stenger received a PhD in physics from Humboldt University of Berlin. After a post-doctoral research appointment at the University of California, Berkeley, he joined the Straus Center for Conservation at the Harvard Art Museums in 2004 as a fellow in conservation science. Following his fellowship, he continued his research at the Straus Center until 2013 when he joined the Institute for the Preservation of Cultural Heritage at Yale University as an Associate Conservation Scientist.

Soyeon Choi received a Master of Arts and a Certificate of Advanced Study in paper conservation from the State University of New York, College at Buffalo. From 2000 to 2013, she worked as a paper conservator at the Conservation Center for Art and Historic Artifacts, a nonprofit conservation center, in Philadelphia. Since 2013, she works as Head Paper Conservator at Yale Center for British Art in New Haven.

Chelsea Graham received a Master of Art in Archaeology from Lunds Universitet in Lund, Sweden. From 2008 to 2010 she worked as an Archival Assistant in the Nels Nelson North American Archaeology Lab at the American Museum of Natural History. In 2013 she joined the Institute for the Preservation of Cultural Heritage at Yale University as the Digital Imaging Specialist at the Institute's Digitization Lab.

