PHOTOGRAMMETRY AND TRANSMITTED INFRARED IMAGING
TO DOCUMENT THE SUPPORT OF A 19TH C. BRITISH LANDSCAPE PAINTING

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ABSTRACT:
A combination of mobile technologies was used to document the support of a lined, 19th-century British landscape painting to look for any canvas-maker’s stamps or other features on the original canvas that could be correlated with a date when the canvas was supplied. The programme consisted of the capture of visible close-range photogrammetry and generation of a calibrated three-dimensional (3D) surface model, and transmitted infrared (IR) imaging of the painting’s verso. Two canvas-maker’s stamps found in transmitted IR images were partly obscured by the horizontal cross-brace of the stretcher. To allow more detailed comparisons and measurements of the stamps, registered visible and transmitted IR images of the verso were aligned and spatially referenced with the 3D model. A transmitted IR orthophoto of the verso was exported from the 3D model, and measurements of the outer dimensions of the stamps were taken. To capture more of the obscured text of the stamps, additional transmitted IR images were captured with the camera positioned at an angle above and below the stretcher’s cross-brace. The transmitted IR orthophoto exported from the 3D model provided a calibrated reference image to allow correction of the perspective distortion of the angled transmitted IR images of the two stamps. The distortion-corrected images of the stamps were stitched together for archival purposes. The stamps identified the name and location of the canvas supplier in London and established a date range for when the original canvas was supplied (1834 to ca. 1860).

1. INTRODUCTION
A programme of photogrammetry and transmitted IR imaging to document the original canvas support of a lined 19th-century British landscape painting was performed in late 2014. The goals of the present study are to create an archival record of the painting’s support, including the stretcher, canvas, and any labels, inscriptions, or other features that could provide information regarding the history of its origin and subsequent treatments, such as lining. In particular, the investigation was designed to look for and document any canvas-maker’s stamps that could identify the name of the supplier of the original canvas and establish a date range for when the canvas was supplied.

This study was conducted as part of a larger investigation of the materials and history of the painting. The investigations have relied on portable, non-invasive, multispectral and computational imaging technologies, using open-source methods and software, supplemented with well-documented proprietary software as needed and when practical.

This case study does not attempt to compare and select an optimum set of hardware and software tools to meet the study objectives. The techniques described are flexible and can be carried out using a variety of hardware and software, with comparable results. Some examples of studies relevant to these topics are described to place the current study in broader context.

Figure 1: Nineteenth-century oil-on-canvas painting of the Giudecca Canal and Santa Maria della Salute, Venice (92 x 127 cm); colour orthophoto reconstruction from 16 mosaic image cubes and six visible wavebands. © Ken Boydston and Bill Christens-Barry, 2013. Reproduced by permission.

1.1 Description of the Painting Under Study
The 19th-century oil-on-canvas painting in this study depicts a view of the Giudecca Canal and the basilica of Santa Maria della Salute in Venice, Italy (Figure 1). The painting is in landscape orientation and the stretcher’s
dimensions are approximately 92 x 127 cm, which was not a standard commercial size in mid-19th-century Britain (Simon, 2013; Townsend, 1994). The painting is glue-lined onto linen and the tacking edges have been trimmed. It is likely that the stretcher was supplied when the painting was lined (Proudlove, 2015, personal communication). A paper label on the stretcher reads “Original painting by J. M. W. Turner of the Giudecca, Venice.” A reflected visible-range image of the painting’s stretcher and canvas support is shown in Figure 2.

Figure 2: Reflected visible image of the painting’s support.

1.2 Applications of Photogrammetry for Documentation of Paintings

Close-range photogrammetry offers well-documented benefits for the documentation, study, and dissemination of macro-scale 3D cultural heritage objects (3D-ICONS, 2014). Perhaps less widely appreciated are the useful applications of photogrammetry to document canvas paintings, which are often considered only as two-dimensional surfaces, but in reality are 3D objects. These benefits include the ability to make accurate measurements between points on a calibrated 3D model of the surface, remove lens distortion, and produce high-resolution orthorectified images, or orthophotos of the painting.

Multispectral image cubes are stacks of registered images captured using different wavelengths of reflected, fluorescent, or transmitted radiation. They can be aligned with the 3D model, which provides the capability to stitch together high-resolution images of the entire painting surface in different wavebands. These images are useful for comparing, analysing, and spatially correlating details in various wavebands, within the context of visible features on the painting’s overall surface.

Under certain conditions, discrete images of an object captured from different camera positions can be aligned with the 3D model, and the discrete images can be exported from the 3D model in a combined image such that the spatial relationships among the images of the object are correct. The benefit of such spatial referencing was exploited in this study. For planning and further research, a high-resolution 3D model can be useful as an aid in the selection and documentation of locations for non-invasive analysis or invasive sampling, and provides a framework for spatial correlation of data gathered using other analytical techniques.

A variety of commercial and open-source photogrammetry software is available for generating 3D models from digital images captured using consumer-quality digital cameras and equipment, and new software packages are being rapidly developed and introduced. Inter-comparison studies of the accuracy of results that can be achieved using various software packages have not kept pace with the introduction of new software. Inter-comparisons of the Semi-Global Matching (SGM) algorithm used in an earlier version of Agisoft Photoscan Pro, a commercial software package, later versions of which (ver. 1.0.4 and later) were used in this study, and other categories of stereo-image feature matching algorithms, are presented in Dall’Asta and Roncella (2014) and Remondino, et al. (2014). Fortunately, the guidelines for capturing high-quality stereoscopic image data sets for close-range photogrammetry are largely independent of the photogrammetry software used to process these images. Therefore, the image data sets can be reprocessed as new and better software is developed. Examples of such image capture guidelines are presented in Matthews (2008), Mudge, et al. (2010), and Barsanti, et al. (2014).

An example of the use of photogrammetry to document a large and complex multimedia canvas painting was presented in a study of the Westminster Retable (Robson et al. 2004). This study also demonstrated the use of a 3D model to allow spatial referencing of discrete images documenting the progress of conservation of the object in a geographic information system (GIS) database.

Abate et al. (2014) presented a case study of the application of range-based (structured light) and image-based (photogrammetry) surveys of panel and oil-on-canvas paintings, to document the paintings’ condition and monitor structural changes over time, with a reported spatial resolution of ca. 0.2 mm. Their study demonstrated a method introducing target spheres to tie the 3D models of both sides of the painting to a common reference frame.

1.3 Applications of Transmitted IR Imaging for Documentation of Lined Paintings

Transmitted IR imaging can be useful for revealing canvas-makers’ stamps, inscriptions, underdrawings, or other markings that would otherwise be obscured by layers such as lining canvases, mounts, or paint. Certain pigments that are relatively non-transparent in reflected IR, such as lead white, can be quite transparent to transmitted IR radiation (Frey, et al., 2011). Transmitted IR imaging can often reveal changes in composition when other techniques, such as x-radiography, are not as effective because the x-rays are strongly absorbed by lead white ground layers (Frey, et al., 2011). Transmitted IR imaging can also be an effective technique for documenting patterns of craquelure (Kronkright, 2015, personal communication).

Lining, using animal-based glue as a method for stabilising or repairing deteriorated oil-on-canvas paintings, was a treatment practiced in the late 19th through mid-20th centuries and continued into the late-
20th century, using wax adhesive (Townsend, 1994). Some stretched canvases supplied by Thomas Brown of 163 High Holborn, London, in the 1830s and 1840s were supplied with a loose lining canvas, and canvas-maker’s stamps can sometimes be found on the verso of the primary or the lining canvas, stretcher, or various combinations of these locations (Butlin, 1981). As a result of later relining, canvas-maker’s stamps and other features of the original or primary canvas, such as canvas-weave patterns, are obscured by the lining.

Kushel (1985) described applications of IR-sensitive photographic films or a vidicon imager for transmitted IR study of paintings. Moutsatsou et al. (2011) presented examples of the use of transmitted IR imaging for examination of underpainting and underdrawings found in three canvas paintings from the collection of the National Gallery—Alexandros Soutzos Museum, in Athens, Greece. An example of the use of transmitted IR imaging to document inscriptions on a lined trompe l’oeil painting, The Cup We All Race 4 by Fredrick Peto (1905), is presented in the magazine of the Fine Arts Museums of San Francisco (Hodge, ed., 2014).

2. EARLIER RESEARCH

Previous imaging studies of the subject painting are summarised to place the current study in context. These studies included visible-wavelength Reflectance Transformation Imaging (RTI) and photogrammetry of the recto in 2012 (Bennett, 2013), and comprehensive multispectral imaging of the recto in 2013 (Bennett, et al. 2014).

2.1 Reflectance Transformation Imaging

Visible-range RTIs were captured in October 2012 using the highlight capture method (Cultural Heritage Imaging, 2010). To obtain the target ground sample distance of 0.05 mm, the RTIs were captured in a mosaic pattern of six rows and six columns, with approximately 10 per cent overlap of the capture areas. Higher-resolution RTIs were captured of details on the recto and verso, including fingerprints and a paper label on the stretcher.

2.2 Photogrammetry

Photogrammetry of the recto was captured in October 2012, with ground sample distances ranging from approximately 0.05 mm to 0.07 mm. The images were processed using Agisoft Photoscan Pro software. The resulting dense point cloud contains approximately 86 million points, and the polygonal model is comprised of approximately 20 million polygons for a surface area of approximately 1.1 m².

2.3 Multispectral Imaging

Multispectral imaging of the recto was performed in August 2013 using a 50 megapixel monochrome camera designed by Megavision of Santa Barbara, California, USA. The multispectral images were captured in a mosaic of four rows and four columns to obtain a ground sample distance of 0.06 mm. A two-panel multispectral light-emitting diode (LED) system designed by Equipoise Imaging, LLC of Ellicott City, Maryland, USA was used, with one LED for each of twelve wavebands: one ultraviolet (UV; 365 nm), six visible (455, 470, 505, 535, 570, and 625 nm), and five IR (700, 735, 780, 870, and 940 nm) wavebands. UV reflectance, UV-induced visible fluorescence, and blue-induced visible fluorescence were captured. Controlling the wavelength of the light source using narrow-waveband LEDs reduces the amount of potentially damaging light on the painting’s surface and allows multispectral images to be captured with precise image registration. Filters are used on the camera lens only for UV- and blue-induced visible fluorescence images to isolate the visible wavebands of interest.

Visible-range images in six wavebands were captured using bilateral (both LED panels) and unilateral (single LED panel on the right side) lighting setups. The bilateral lighting setup provides more even lighting, while the unilateral lighting setup reveals more of the texture of the painting’s surface. Images were flat-fielded, calibrated and processed using MegaVision Photoshoot software.

2.4 Alignment and Export of Multispectral Orthophotos

The 16 image cubes consisting of 12 wavebands plus fluorescence, unilateral and bilateral colour reconstructions, and false-colour combinations were aligned with the 3D model so they could be exported as orthophotos of the entire painting’s surface. This was done by consistently naming the images representing each of the 12-plus wavebands of the 16 image cubes, and placing the renamed images into separate folders for each waveband or colour reconstruction in the file structure. This resulted in 16 mosaic images in each subfolder per waveband. The 16 visible colour reconstructions were aligned with the 3D model using feature detection algorithms in the Agisoft Photoscan Pro software, so that a visible colour orthophoto could be exported. Complete orthophotos of each of the wavebands could then be exported from the 3D model simply by selecting the path of the images in the model to point to the folder containing 16 images for each waveband or false-colour reconstruction.

3. METHODS

Documentation of the painting’s support consisted of visible close-range photogrammetry; transmitted IR imaging of the canvas; alignment of transmitted IR images with the 3D model; measurement; detailed transmitted IR imaging of the canvas maker’s stamps; correction of image distortion; and stitching complete images of the stamps.

The camera used for both photogrammetry and transmitted IR imaging for this study is a mirrorless, micro four-thirds (MFT) format camera (Panasonic model DMC-GH2), which was modified by removing the internal filter on the sensor to allow UV, visible, and IR imaging. The conversion was done by LifePixel of Mukilteo, Washington, USA. The modified camera sensor is sensitive to wavelengths from approximately 340 to 1,100 nm. The sensor contains an effective array of 3456 x 4608 pixels (approximately 16 megapixels), which has dimensions of 13.0 x 17.3 mm, for a pixel pitch of 3.76 µm. The equivalent focal lengths of lenses for full-frame (35 mm format) digital single-lens reflex (DSLR) cameras are approximately twice the focal lengths of lenses for the
MFT format; hence, a 20-mm lens on an MFT camera is approximately equivalent to a 40-mm lens on a full-frame DSLR.

### 3.1 Photogrammetry

Photogrammetry of the verso was performed in August 2014.

#### 3.1.1 Equipment, Setup, and Capture

The painting was staged vertically on an easel that allowed the painting to be raised and lowered using a hand-crank. The camera was placed on a tripod with an adjustable vertical column and a horizontal focusing rail to allow refocusing, if necessary, by moving the camera closer or farther from the painting without changing the lens focus ring, which would otherwise alter the lens calibration parameters. The camera was mounted on a rotation device made by Really Right Stuff of Santa Barbara, California, USA, which allowed the camera to be rotated +/- 90 degrees around the optical axis to capture lens calibration images without shifting the tripod head.

Photogrammetry images were captured using a 14- to 42-mm zoom lens set at a focal length of 14 mm (equivalent to 28 mm on a full-frame DSLR) with an aperture of f/8. The zoom and focus rings of the camera were taped to prevent changes during the capture sequence. Since the camera was modified to allow UV, visible, and IR imaging by removing the internal filters on the sensor, a UV- and IR-blocking filter (CC1 filter supplied by LDP LLC) was placed on the lens for visible-range imaging.

The camera was placed with the sensor at a distance of approximately 35 cm from the stretcher. To achieve sufficient overlap between stereo-images, the camera was shifted approximately 13 cm horizontally and 9 cm vertically, resulting in a base-distance ratio (ratio of sensor distance to lateral camera shift between horizontal positions) of approximately 3. This provided good geometry for the photogrammetry calculations and helped to reduce occlusions around the structural members of the stretcher. The ground sample distance was approximately 0.07 mm. The visible images were captured in 8 rows and 11 columns, with approximately 86 percent horizontal overlap and 34 percent vertical overlap for the landscape-oriented images. A total of 264 images were captured and used to generate the 3D model: 88 horizontal images and 176 rotated images for lens calibration (three images per camera position). Additional images were captured at the ends and middle of each row with an X-Rite Passport colour checker card included in the image for colour profiling purposes and to maintain consistent colour balance.

A bilateral lighting setup was used: two 65-watt tungsten incandescent lights with 10-inch reflectors were placed at the vertical height of the camera at angles of approximately 45 degrees from the plane of the stretcher.

#### 3.1.2 Image Processing and Generation of 3D Model

The images were captured in RAW format, converted to Digital Negative (DNG) format, and corrected for colour, exposure, and white balance in Adobe Lightroom 4 with the X-Rite Color Checker Passport plug-in. The images were then exported as 16-bit TIFFs for processing into a 3D model using Agisoft Photoscan Pro software. All 264 images were aligned and calibrated as one group. The resulting dense point-cloud contains approximately 52 million points, and the polygonal model contains approximately 10 million polygons for a surface area of approximately 1.1 m². The steps in the photogrammetry processing sequence, alignment, optimisation of the sparse point cloud, and generation of the dense point cloud and polygonal mesh, were automatically recorded in log files.

### 3.2 Transmitted IR Imaging of Canvas

Transmitted IR imaging of the canvas was performed during a four-day period in October-November 2014. The imaging was conducted in several steps, consisting of an initial survey of four quadrants of the canvas at low resolution; more detailed imaging of two partially obscured canvas stamps that were identified on the low-resolution images; alignment of the low- and high-resolution images with the 3D model and orthophoto export; measurement of the canvas stamps; and additional transmitted IR imaging of the stamps with the camera placed at an angle to the plane of the canvas to reveal more of the partially obscured stamps. These steps are described below.

#### 3.2.1 Equipment, Setup, and Capture

The painting was staged vertically on the same easel used for photogrammetry, except that it was placed with the verso facing away from the easel rails. The recto was protected by a sheet of foam core, which was repositioned as needed to allow transmitted IR radiation through the portion of the canvas being photographed. A backdrop of black muslin was erected from floor to ceiling on each side of the canvas, with black construction paper above and below the canvas, to block stray ambient IR light. For image naming purposes, the four areas of the canvas bounded by the vertical and horizontal cross-braces and the perimeter of the stretcher were identified as Quadrants 1 through 4, numbered clockwise starting from the top right quadrant (Figure 3).

A 20-mm normal lens (equivalent to 40 mm on a full-frame DSLR) was used to capture both visible and transmitted IR images. Reflected visible images were captured with a UV and IR blocking filter (CC1 filter supplied by LDP LLC). Transmitted IR images were captured with an IR bandpass filter that transmits wavelengths from approximately 660 to 750 nm (BPB filter supplied by LDP LLC). Various other IR bandpass and cutoff filters transmitting IR wavelengths extending to 1,100 nm were tried, but the BPB filter provided the best contrast for the two canvas stamps that were found.

Reflected visible and transmitted IR Images of each quadrant were captured as registered pairs with the camera positioned with the sensor at a distance of approximately 70 cm from the canvas, with a ground sample distance of approximately 0.13 mm. The purpose of these images was to survey the original canvas for canvas maker’s stamps or other markings that could provide information about the source and date of the original canvas. The visible images provided references to correlate the locations of any features identified on the original canvas in the transmitted IR images, and were also used to align the transmitted IR images with the 3D model of the verso generated from photogrammetry (Section 3.1). The reflected visible image capture
sequences included an X-Rite Passport colour checker card for colour profiling purposes and to maintain consistent colour balance.

To capture reflected visible images of each quadrant of the canvas, a radio remote trigger was used to trigger a pair of Canon 580EX speedlights that were synchronised to the camera shutter. The source of transmitted IR radiation was a single, 500-watt tungsten-halogen lamp facing the recto of the painting at a distance of approximately 1 m. To reduce heating and photonic exposure, the 500-watt lamp was rotated away from the painting and a sheet of foam-core was placed in front of the painting between transmitted IR exposures, which ranged from 30 to 60 seconds.

After two canvas stamps were identified (Section 4.1), more detailed registered pairs of reflected visible and transmitted IR images of the stamps were captured by repositioning the camera closer to the canvas, with the sensor at a distance of approximately 11 cm, obtaining a ground sample distance of approximately 0.03 mm.

3.2.2 Image Processing: The RAW images were converted to DNG format. Reflected visible images were corrected for colour, exposure, and white balance in Adobe Lightroom 4 with the X-Rite Colour Checker Passport plug-in. Transmitted IR images were converted to grey-scale and adjusted for exposure. The images were then exported as 16-bit TIFFs. The registered pairs of reflected visible and transmitted IR images were renamed consistently as pairs and placed in separate folders for reflected visible and transmitted IR to allow the images to be aligned with the 3D model.

3.2.3 Alignment of Reflected Visible and Transmitted IR Images to the 3D Model: The four low-resolution reflected visible images of the four quadrants of the verso and four high-resolution reflected visible images of the canvas stamps were imported into Agisoft Photoscan Pro and aligned with the 3D model using feature detection algorithms built into the software. After the reflected visible images were aligned with the model, the paths to the reflected visible images were changed to point to the folder containing the registered transmitted IR images to allow export of a transmitted IR orthophoto.

3.2.4 Export of Transmitted IR Orthophoto: A transmitted IR orthophoto was exported from Agisoft Photoscan Pro by disabling the reflected visible images used to construct the model (except for the visible image that contained the scale for the 3D model), and leaving the transmitted IR images enabled. The transmitted infrared orthophoto was exported as an 8-bit TIFF showing the four quadrants and canvas stamps spatially referenced (Figure 3).

3.2.5 Measurement: The outer dimensions of the spatially referenced canvas stamps were measured by opening the transmitted IR orthophoto in ImageJ, an open-source image analysis program (Rasband, 1997–2014). Points on the visible scale in the orthorectified image were used to set an image scale, and measurement tools in ImageJ were used to measure the height and width of Stamp A, which has more clearly defined borders around its perimeter than does Stamp B (Figures 4 through 7). The dimensions of Stamp B were not measured because the incomplete borders were obscured by the stretcher’s cross-brace and were not visible in the orthophoto.

3.2.6 Angled Transmitted IR Imaging of Canvas Maker’s Stamps: To provide more complete documentation of the stamps, including areas that were obscured behind the stretcher, additional detailed transmitted IR imaging of the stamps was undertaken with the camera placed at an angle of approximately 30 degrees (+/- 5 degrees) to the plane of the canvas. Tapered wooden shims were placed on either side of the stamps between the horizontal cross-brace of the stretcher and the canvas to open a narrow gap of approximately 0.75 cm. With the camera positioned at a downward angle from above and upward angle from below the cross-brace of the stretcher, most of the text of each of the halves of the stamps could be captured in transmitted infrared images (Figures 8 through 11).

3.2.7 Correction of Perspective Distortion and Stitching Complete Images of Stamps A and B: To correct the perspective distortion of the transmitted IR images of the canvas stamps caused by the angle of the camera, the images shown in Figures 8 through 11 were opened in Adobe Photoshop CS6, along with the transmitted IR orthophoto of the four spatially referenced quadrants exported from the 3D model. The angle images were copied as semi-transparent layers on the orthophoto and the distortion was corrected by eye using the perspective, skew, and scale tools. When the corrections appeared to match the orthophoto as closely as possible, the angle images were stitched together to render both Stamps A and B as completely as possible for comparison (Figures 12 and 13). These processing steps were recorded in log files automatically generated by setting preferences in Photoshop.
4. RESULTS AND DISCUSSION

4.1 Results of Initial Transmitted IR Imaging

Two canvas maker’s stamps on the original canvas were observed in the transmitted IR images of the four quadrants, and identified as Stamps A and B. The canvas stamps are rotated 90 degrees counter-clockwise from the horizontal landscape orientation of the painting and are vertically centred behind the horizontal cross-brace of the stretcher (Figure 3).

Because the stamps are partially obscured by the stretcher, only the border edges and a few letters of the stamps are visible in the transmitted IR images captured with the camera oriented perpendicular to the plane of the canvas. (Figures 4 through 7). The dimensions of Stamp A are 6.1 cm high x 11.4 cm wide. The dimensions of Stamp B were not measured because the incomplete borders were obscured by the stretcher’s cross-brace and not visible in the orthophoto.

Figure 3. Transmitted IR orthophoto showing the locations of two canvas stamps on the original canvas. For ease of reference to the stamps, the canvas is divided into four quadrants numbered 1 through 4, starting from the upper-right quadrant and continuing clockwise to the upper left quadrant.
Figure 4. Detail of Stamp A, quadrant 2, rotated 90 degrees clockwise.

Figure 5. Detail of Stamp A, quadrant 1, rotated 90 degrees clockwise.

Figure 6. Detail of Stamp B, quadrant 3, rotated 90 degrees clockwise.

Figure 7. Detail of Stamp B, quadrant 4, rotated 90 degrees clockwise.
4.2 Results of Angled Transmitted IR Imaging of Canvas Maker’s Stamps

With the camera positioned at a downward angle from above and upward angle from below the cross-brace of the stretcher, most of the text of each of the halves of the stamps could be captured in transmitted infrared images (Figures 8 through 11).

Figure 8. Transmitted IR image of Stamp A, quadrant 2, captured at an angle of approx. 30 degrees to the canvas.

Figure 9. Transmitted IR image of Stamp A, quadrant 1, captured at an angle of approx. 30 degrees to the canvas.

Figure 10. Transmitted IR image of Stamp B, quadrant 3, captured at an angle of approx. 30 degrees to the canvas.

Figure 11. Transmitted IR image of Stamp B, quadrant 4, captured at an angle of approx. 30 degrees to the canvas.

Figure 12. Stitched transmitted IR image of Stamp A with perspective distortion corrected in Adobe Photoshop CS6. Image is rotated 90 degrees clockwise.

Figure 13. Stitched transmitted IR image of Stamp B with perspective distortion corrected in Adobe Photoshop CS6. Image is rotated 90 degrees clockwise (part of the stretcher is visible in the centre of both images of Stamps A and B).

4.3 Correction of Perspective Distortion and Stitching Complete Images of Stamps A and B

The stitched images of Stamps A and B are shown in Figures 12 and 13 after correction of the angle distortion.
4.4 Discussion

4.4.1 Comparison of Canvas Stamps: The most easily observed difference between the two stamps is the apparent absence of a border around the left and right sides of Stamp B. The partial border at the top and bottom of Stamp B was visible in the angled transmitted IR images, and was measured in the stitched image with perspective correction to be approximately the same height as Stamp A, 6.1 cm (Figure 13). The incomplete border and other differences between the two stamps could be attributable to inconsistent application of ink using a stencil.

The positions of the two stamps, which are centred vertically on the stretcher and rotated 90 degrees counter-clockwise relative to the landscape orientation of the painting, combined with the non-standard dimensions of the canvas, suggest that the canvas was supplied as a roll and stretched by the artist, or perhaps by an assistant, onto the original stretcher, which might have lacked a horizontal cross-brace. The construction of the stretcher suggests that it might have been supplied when the painting was lined (Proudlove, 2015, personal communication).

4.4.2 Interpretation of Stamps: With the perspective distortion corrected, and the two halves of the stamps stitched together, most of the text of the stamps can be more easily read, as follows:

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H...LT
ARTISTS...COLOURMAN
80 GOS...LL ROAD
Opposite...[illegible]
ISL...TON
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The text of the stamps is interpreted as reading “Holt/ Artists’ Colourman/ 80 Goswell Road/ Opposite [illegible]/ Islington.” This interpretation was confirmed by a record of Andrew Bruce Holt (1830 – 1896), an artists’ colourman, in an on-line database of artists’ suppliers in Britain and Ireland (Compton, 2011). Further unpublished research by this author and others using on-line databases, genealogical records, and London trade and post office directories, identified two generations of the Holt family who were active as artists’ colourmen and related occupations from 1834 until ca. 1860. After 1860, members of the Holt family diverged into other occupations, perhaps motivated by changing economic conditions. Available records indicate that Andrew’s father, John Holt (ca. 1802 – 1874), was active as an oil and colourman, artists’ colourman, and related occupations at 31 East St. (now called Chiltern St.), Marylebone, near Manchester Square, and at 80 Goswell Road, in the borough of Islington, London, from 1834 to ca. 1856.

The 80 Goswell Road address has changed since the late 1800s. The street index for Goswell Road in the 1856 Post Office London Directory indicates that 80 Goswell Road was the third in a series of addresses formerly numbered 78, 79, and 80 on the west side of Goswell Road, north of the intersection of Owens Row and near the present location of the Angel Inn (Kelly’s, 1856). These three addresses were part of an extended row of 18th-century buildings known as Gwynne’s Buildings and were apparently demolished sometime before 1901, probably during the expansion of Dame Alice Owen’s Boy’s School from 1879 to 1896 (Temple, 2008).

5. CONCLUSIONS AND FUTURE WORK

5.1 Conclusions

The portable methods used in this study demonstrate the effectiveness of transmitted IR imaging to reveal canvas maker’s stamps and potentially other inscriptions or markings on lined canvases, including canvases which have a lead white ground layer. The benefits of photogrammetry include the ability to spatially reference images, export high-resolution orthophotos from a 3D model of an object, measure features, and view details in the context of the whole object. The orthophoto generated from the 3D model of the verso allowed the perspective distortion of images captured at an angle to the canvas plane to be corrected, so nearly complete images of the canvas stamps could be stitched together for archival purposes. The 3D model also provides a spatial reference that can be used to correlate images and data gathered from future studies.

5.2 Future Work

Among suggested improvements to the methods used in this study would be to include additional overlapping reflected visible-range calibration images with the registered pairs of visible and transmitted IR images, as well as for any subsequent images intended for spatial referencing with the 3D model. These would allow more accurate alignment and calibration of the images with the model and would also allow more accurate measurements by establishing tie points between the 3D model and subsequent images.

Another improvement would be to include target spheres to allow both recto and verso of the painting to be tied to a common coordinate system (Abate, et al., 2014). Since photogrammetry images were captured of the recto in 2012 and of the verso in 2014, this was not done for this study, but could easily be done in the future.

Additional historical research is needed to better understand the dates and locations of the Holt family’s businesses, particularly during the period from 1844 to 1851, when no records of businesses operating at 80 Goswell Road were found. The possible existence of other paintings using canvases supplied by Holt will be explored. Additional targeted surveys of canvas paintings of similar sizes and subjects from the time frame between ca. 1830 to ca. 1850, using transmitted IR imaging, could provide useful information about the suppliers of canvases for J. M. W. Turner, many of whose paintings have been lined (Butlin, 1981 and Townsend, 1994), as well as those for questioned or unattributed works by other important artists. Investigations into the materials and history of this painting are continuing.

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6. REFERENCES


Hodge, D., ed., 2014. The Cup We All Race 4: recent technical findings. In: Fine Arts, Summer, San Francisco, USA.


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Agisoft (http://agisoft.com) allowed the author to purchase a license for their Photoscan Pro software at an educational discount.