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NCPTT Preservation Technology and Training Grant
Historic Blenheim Graffiti Multispectral Imaging

December 2020 – January 2021

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1 Multispectral Imaging at Historic Blenheim

This data set includes captured and processed data from the multispectral imaging by R.B. Toth Associates LLC of key regions of interest (ROI) on the walls of the Civil War era Historic Blenheim in Fairfax City, Virginia, USA on 15-19, 21 and 23 December 2020. This imaging supports conservation research and scholarship under a Preservation Technology and Training Grant from the National Park Service, National Center for Preservation Technology and Training. It follows R.B. Toth Associates pro bono test multispectral imaging of ROIs on the ground floor on 19 June 2019.

This advanced multispectral imaging produced standardized multispectral images with the data structure needed to support digital preservation and access of all the images. The data also supports optimization of spectral analysis and potential follow-up scientific and/or research studies with additional technologies. This promotes greater public and private participation in historic preservation programs and activities, providing new knowledge through research. Dissemination of these images will support research into features and residues of importance for conservation and scholarship can be detected. This will support development of appropriate conservation techniques for the interior walls of historic structures.

The narrowband multispectral imaging system used for this project includes commercial-off-the-shelf hardware and software for digital spectral image capture and viewing with the integrated system. The system operations are integrated with the Spectral XV system software that controls the camera, illumination panels and filters with a one-button user interface. It also includes customized image processing software for exploitation of the spectral images, provided in partnership by Equipoise Imaging LLC.

The portable multispectral imaging system was installed in Historic Blenheim and moved from room to room for imaging. The camera and integrated filters (below) were mounted on a tripod (or tripods for safety), and the light panels were mounted on separate light stands, all connected to a laptop computer and power.

Each image contains a reference ruler and color chart that was affixed to be visible in the lower left of each image. The ROI designation affixed to the center of the reference ruler for quality control and verification of the image. The reference ruler uses a millimeter scale, but is 12 inches long by 6 inches high. Imaging was conducted in darkened rooms to avoid broadband illumination.

1.1 Camera System

The camera system utilizes a Phase One iXG camera with a 100 Megapixel achromatic CMOS sensor and Schneider Kreuznach 72 mm lens. Image data were downloaded in at the end of each capture via USB 3.0 connection to a laptop computer.

1.2 Illumination System

The imaging system provides narrowband illumination with light in 16 specific wavelengths from low heat and low maintenance, long-lifetime light emitting diodes (LEDs). It includes two integrated illuminators, each with multiple LEDs, providing illumination for imaging in at least 14 distinct ultraviolet, visible and infrared spectral bands (see wavelengths in "General File Conventions" below). It is integrated with software to allow simplified system operation and unified metadata capture.

1.3 Filter System

To capture fluorescence from the walls, a 6-position motorized filter wheel contains 50 mm square optical glass filters, with control software and computer interface. Filtered images increase the range of captured information to include both fluorescence emissions and UV reflectance. This allows the characteristic spectra of substrate, colorant, and contaminant materials to be more completely determined and analyzed. The filter wheel is driven by computer control with a removable carousel containing a selection of filters (UV bandpass; visible bandpass and longpass filters).

1.4 Image Capture Integration

The Spectral XV integrated image capture operating software provides integrated control of the digital camera back, filters and illumination as a single system. This software – based on the CaptureCore application engine developed by Phase One A/S to control camera capture operations and processing workflow – allows streamlined operation and metadata capture from a single interface with simple setup and imaging. This includes naming each image data file and entering the metadata for each image into the TIFF header and an associated json file (a standard data interchange format that can be read as a text file).

1.5 Spectral Imaging Processing

Some images were processed with ImageJ open-source image processing software and a customized Paleo Toolbox to conduct statistical principal components analysis (PCA). This is a spectral imaging toolkit created by Dr. Bill Christens-Barry of Equipoise Imaging, LLC, for applications in cultural heritage imaging. The Paleo toolkit comprises plugin modules that integrate into ImageJ, an open source image processing tool originally developed at the US National Institutes of Health. ImageJ has been widely adopted and extended by scientists working in remote sensing, biological science, and cultural heritage world-wide. It offers a wide range of digital operations for the enhancement and reproduction of non-visible features from the objects based on their spectral response in images captured with the full set of illumination wavelengths and emission bands. Further collaborative processing of key areas of interest offer the potential to reveal more information.

2 Rights

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3 Historic Blenheim Spatial System

A spatial standard was established to accurately designate location of regions on the Historic Blenheim walls. Historic Blenheim is not aligned to cardinal compass points, so a lettering and numbering system was used to designate image locations.

Rooms

Three digit room numbers from the architectural plans were used, e.g. Left Front Parlor is Room 101, etc. (Attic 301 and Room 302 were used for the two attic rooms.)

Walls

Interior walls of each room were assigned letters in a clockwise fashion facing into the house from the front door:

A. Left Wall: A,
B. Back (facing) Wall: B
C. Right Wall: C
D. Front (entry) Wall: D

Regions

Broad areas on each wall were divided by numbers from left to right facing the wall, usually with wall features serving to differentiate the region, e.g. in Room 101 fireplace wall the area to the left of the fireplace is Region 1, over the fireplace Region 2, and right of the fireplace Region 3.

Regions were further subdivided with lower case letters starting with the letter 'a' from left to right, e.g. first region to the left is 'a', region to the right is 'b', etc. They were divided vertically with numbers from 1 at the top, e.g. top region is 1, next down is 2, etc.

4 Historic Blenheim Data Set Contents

The Historic Blenheim data set comprises a core content set of digital images of the areas imaged in December 2020 and January 2021. It contains the following folders with multispectral image data. Each folder corresponds to a stack of 21 images of a wall region within Historic Blenheim, with each image captured using a different illumination and/or filter, while the final 0000 image is a "dark shot" with no illumination capturing only the ambient light. Due to the ever-changing imaging system setup throughout the house, only a single calibration stack was captured, with a large white sheet and color chart in the scene.

The image data comprises:

Data

"Blenheim"

- Blenheim_Attic301-A1A2
- Blenheim_Attic301-A2A3
- Blenheim_Attic301-A3a
- Blenheim_Attic301-A3b
- Blenheim_Attic301-B3
- Blenheim_Attic301-C1
- Blenheim_Attic301-D3
- Blenheim_Rm100-A2a1
- Blenheim_Rm100-A2a5
- Blenheim_Rm100-A3a0
- Blenheim_Rm100-A3a1
- Blenheim_Rm100-A3a2
- Blenheim_Rm100-A3a3
- Blenheim_Rm100-A3B1af
- Blenheim_Rm100-A3B1bk
- Blenheim_Rm100-B3C1a
- Blenheim_Rm100-C2a1k
- Blenheim_Rm100-C2a2k
- Blenheim_Rm100-C2a3
- Blenheim_Rm100-C2b1
- Blenheim_Rm100-C2b2
- Blenheim_Rm100-C2b3
- Blenheim_Rm100-C2c1
- Blenheim_Rm100-C2c2
- Blenheim_Rm100-C2d1
- Blenheim_Rm100-C2d2
- Blenheim_Rm100-C2z1k
- Blenheim_Rm100-C2z2
- Blenheim_Rm100-C3a0
- Blenheim_Rm100-C3a1
- Blenheim_Rm100-C3a2k
- Blenheim_Rm100-C3a3k
- Blenheim_Rm101-A1a
- Blenheim_Rm101-A2a
- Blenheim_Rm101-B3ak
- Blenheim_Rm101-C2a
- Blenheim_Rm101-C2a1
- Blenheim_Rm101-C2bm
- Blenheim_Rm102-B2
- Blenheim_Rm102-B3C1k
- Blenheim_Rm102-C2a
- Blenheim_Rm102-D2ak
- Blenheim_Rm103-A3B1
- Blenheim_Rm103-B2
- Blenheim_Rm104-A2a1
- Blenheim_Rm104-A2a2
- Blenheim_Rm104-A2b1
- Blenheim_Rm104-A2b2
- Blenheim_Rm104-C2a1
- Blenheim_Rm104-C2a2
- Blenheim_Rm104-C2b1
- Blenheim_Rm104-C2b2
- Blenheim_Rm104-Calibration
- Blenheim_Rm200-A2a
- Blenheim_Rm200-A2ab
- Blenheim_Rm200-A2ak
- Blenheim_Rm200-A2b
- Blenheim_Rm302-A3
- Blenheim_Rm302-A31
- Blenheim_Rm302-C1C2
- Blenheim_Rm302-C1C2z
- Blenheim_Rm302-C2C3
- Blenheim_Rm302-C3a
- Blenheim_Rm302-D1
- Blenheim_Rm302-D1b
- Blenheim_Rm302-D1c
- Blenheim_Rm302-D1D2z
- Blenheim_Rm302-D2
- Blenheim_Rm302-D2a2
- Blenheim_Rm302-D2b
- Blenheim_Rm302-D2b2
- Processed PCAs
- jsons

4.1 Core Data

For each region of interest, the data set provides captured registered TIFF images with metadata, as well as digitally processed images of key ROIs. These images should be retained as archival images and viewed with most image viewers.

These images were converted from the Phase One proprietary .IIQ format to 16-bit .TIF format with Capture One Software and the “linear scientific” curve. Converted images have the "_R" at the end of the rootname. There are no flattened images.

The core data includes:

- Captured Image data consisting of TIFF images. These are individual images from each of the imaging systems taken with different energy levels of light. Images were not flattened due to the different camera and lighting setup required for each image stack.
- Computer Processed images. Images that have been digitally produced through the application of computer algorithms to combine and enhance captured images to enhance visibility of manuscripts artifacts and text. All processed images are TIFF or jpeg images, or AVI video clips of a series of processed images.

Each multispectral capture image folder is provided with descriptive metadata in the JSON file giving details of the image capture for the project, scene and stack of images and processing methods used to generate integrated images from the various captured images. These follow the Archimedes Palimpsest Metadata Standard for multispectral images, which includes key Dublin Core Metadata Elements http://archimedespalimpsest.net/Documents/Internal/Image_Metadata_Standard.pdf

Metadata in the Project JSON includes the following metadata elements at the “Project” and “Scene” level, with technical collection details included at the “Stack” level:

"Project":

"ProjectID": "100001",

"Name": "Blenheim",

"Rights": "CC0",

"Publisher": "City of Fairfax",

"ProjectNickName": "Blenheim",

"Creator": "R.B. Toth Associates",

"Contributors": "MB Toth, Andrea Loewenwarter, Susan Gray, Bill Christens-Barry, Jim Anderson, Historic Blenheim Staff and Volunteers, Mills Kelly, NPS NCPTT",

"Description": "NCPTT Preservation Research Grant for multispectral imaging studies of preservation risks and soldiers' graffiti on walls of Civil War era house",

"Location": "City of Fairfax, Virginia USA",

"Scenes": [

"Subject": "Room 100",

"SceneNickName": "Rm100",

"SceneStatus": "ToDo",

"SceVisibilityStatus": 1,

"Date": "2020-12-14T10:43:51.2689343-05:00",

"Language": "TBD",

"Source": "Historic Blenheim",

"CoordinateUnits": "inch",

"OriginalSceneVersion": "2.1.1.3",

"SceneDesc": "Main Floor entry and hallway",

"Stacks": [

"Identifier": "C2a1",

"StackNickName": "C2a1",

"Creator": "R.B. Toth Associates",

"Contributors": "MB Toth, Andrea Loewenwarter, Susan Gray, Bill Christens-Barry, Jim Anderson, Historic Blenheim Staff and Volunteers, Mills Kelly, NPS NCPTT",

"StkNumShots": 23,

5 General File Conventions

The captured images file names include six fields plus an extension. The initial three fields match the short forms of the project name, scene name, and image stack name. The first and second fields are delimited by "_" (underscore), and the second and third fields are delimited by "-" (dash). The fourth field consists of a three digit number, indicating the illumination light wavelength (in nanometers), plus a plus a single letter identifier for the camera filter.

The illumination or illuminations used to produce each image cited in the filename of the flattened images include fifteen illumination types, with one symbol each. The illumination symbol is one of the following symbols, including symbols for the filters used in fluorescent imaging:

- 365 - 365 nm UV LED illumination
- 385 - 385 nm UV LED illumination
- 410 - 410 nm borderline UV-Visible LED illumination
- 450 - 450 nm visible LED illumination
- 480 - 480 nm visible LED illumination
- 510 - 510 nm visible LED illumination
- 550 - 550 nm visible LED illumination
- 600 - 600 nm visible LED illumination
- 630 - 630 nm visible LED illumination
- 640 - 640 nm visible LED illumination
- 660 - 660 nm visible LED illumination
- 740 - 740 nm LED IR illumination
- 850 - 850 nm LED IR illumination
- 940 - 940 nm LED IR illumination
- 000 - No illumination, capturing ambient light only

Filter Symbols

- N = CLEAR (no filter)
- U = BP365 (UV bandpass filter)
- V = LP400 (long pass filter that passes wavelengths longer than 400 nm - blue and above)
- G = LP515 (long pass filter that passes wavelengths longer than 515 nm - green and above)
- R = LP515 (long pass filter that passes wavelengths longer than 590 nm - red and above)
- I = LP715 (long pass filter that passes wavelengths longer than 715 nm - IR and above)

Examples for unflattened captured images are:

Project_Scene-Stack-<wavelength and filter>_<index number>_R.tif

For the "Blenheim" NCPTT project, this yields:

Blenheim_Room-ROI-<wavelength and filter>_<index number>_R.tif

A representative image in the front parlor (Room 101) of the wall (Wall A) to the left of the fireplace (Section 1), in an area to the top left (area a), taken with 940 nm (IR) lights with no filter, which is the 14th shot, yielding:

Blenheim_Rm101-A1a-940N_014_R.tif

Corners formed by two walls have both walls in the filename, e.g. Entry hall back right corner is A3B1. Two sections of a wall are designated with the Wall designation and numbers of both sections, e.g. Attic 301-A1A2.

Some areas were reimaged to adjust lighting or due to a technical or other issue. Reimaging of the same section is designated with the suffix "k" and subsequent letters for subsequent reimaging. Imaging at a distance or oblique angle is designated with the suffix "z".

Principal components analysis (PCA) is a numerical technique for identifying which illumination wavelengths and combinations offer combinations of captured images to help identify and distinguish unique features in image stacks. This can aid visual recognition of faint content that would otherwise be undetected. PCA was used in this study to create monochrome and false color "pseudocolor" output images that could provide additional insight into features on the Interior walls.

Processed images amend this naming convention to indicate the type of processing employed. The initials of the individual who created the processed images are (optionally) given in the fourth field of the filename of processed files. Since processing operations most often utilize all of the captured images of a stack, identification of individual images used as inputs for processing operations are generally omitted. One or more following, underscore-delimited fields describe the processing operations and parameters that were used, appended in order of their application. Within an underscore-delimited field, single hyphens are used to delimit

parameter values or image indices used during that processing operation. Usually the parameters refer to the index number of a component image.

A filename for the captured image stack above exemplifies the naming practices used for processed images:

Blenheim_Attic301-A3a_N_PCA--pc01-pc02-pc03-pc05_PCAN-1--3_RGB.jpg

Project name:	Blenheim
Scene name:	Attic301
Stack name:	A3a
Processing:	1. Principal Components Analysis (PCA) Normalized
	2. PCA components 01, 02, 03 and 05 were used in the R, G, and B channels, respectively, of the final (synthetic) RGB jpg image

Other strings in processed file names include:

"dS8_BasicRGB" an RGB image has been synthesized from flattened images and desaturated computationally by a factor of x0.8;

"8gs" a single channel (grayscale) image stored in 8-bit format

"Combi" multiple grayscale images (captured or propcessed) were use combinatorally to create many different synthetic RGB images. The resulting files are very large, and are usually stored in the "AVI" movie format.

The remainder of the file name, including the extension, indicates the file type. These are usually:

1. TIFF still image files, ending in 'tif',
2. JPEG still image files ending in 'jpg'
3. AVI moving image files ending in ‘avi’