Ashley Freeman, Michael Doutre, George Bevan, and Alison Murray
Queen's University, Kingston, Ontario

Craquelure Documentation and Analysis: A Preliminary Process Using Reflectance Transformation Imaging and ImageJ

Abstract

Craquelure, made up of fine surface cracking patterns, is a common feature of painted works. These patterns can offer much information about the provenance, composition, manufacturing process, and treatment of a painting. Photographic methods are used to document the condition of a painting and preserve information thereby revealing the work's history. Standard photographic techniques, however, often capture fine crack patterns poorly. Reflectance transformation imaging (RTI) is a photographic technique that, by mapping an object's surface normal, exposes features that are ordinarily hard to observe. In this work, the drying crack morphologies of a variety of gessoes were captured. Two calcium carbonate gessoes were prepared with different binders; rabbit skin glue (RSG) and Aquazol 500. The effect of the materials on crack propagation with drying was examined as a function of binder type. RTI was used to enhance the cracks more than would be possible with standard photographic techniques, thus allowing for accurate computational identification and quantification of the fine crack patterns.

Introduction

Photography in Art Conservation

In the art conservation field, photography is an essential technique. Photography using reflected, raking, infrared, and ultraviolet light is often used to document the condition of an artwork and the progression of a treatment. With some of these techniques, in particular raking and reflected light photography, specific surface features are emphasized while others are not. This directional bias is the result of the light source, which only illuminates certain details of the object. If an object were to be illuminated from numerous known directions and the specific illuminations captured, more data would be collected and all the object's three-dimensional information would be observed. In recent years, conservators, archaeologists, and practitioners of other disciplines have been using reflectance transformation imaging (RTI) to document three-dimensional information [1-9]. This process results in images with the contrast of raking light but without a directional illumination bias. The RTI images of an object, especially a painting, can shine light on its various morphologies, making flaking, structural changes, impasto, tool markings, and fine cracks more evident.

Crack Description

For this project, the literature was surveyed to determine the nomenclature that would best describe craquelure and determined using ImageJ. Stout's article "Trial Index of Laminal Disruption" called attention to the lack of a specialized language within the conservation field and laid out a schematic for describing laminal disruptions (fissures and cleavage) [10]. To help standardize language within the conservation field, the article depicted over 30 drawings of parallel (cleavage) and perpendicular (cracks) disruptions. The CCI note 10/11 defined terms used in other information, such as how to describe the location of cracks in the painting structure [11]. Crack patterns were named with reference to other well-known patterns; for example, alligator cracks were cracks that looked similar to alligator skin. Bucklow's article "A Stylometric Analysis of Craquelure" outlined eight dichotomies for the descriptive terms of craquelure [12].

ImageJ, an image-processing program, was used to process the collected data, as it was freely accessible. The functions available within ImageJ, and the information in the previously mentioned articles, lead to identification of the following quantifiable terms for describing a crack pattern using ImageJ: junctions (where cracks meet such as triple points or quadruple points), crack density, crack length, directionally of the individual cracks, and area of islands. For this research, an island was described using Bucklow's definition as "a closed area delineated by a number of cracks".

Method

Sample Preparation

To prepare the samples, a de-crimped, unsized, and unbleached cotton canvas was stretched onto stretcher frames and sized with carbon black bound in 50 gL^{-1} rabbit skin glue (RSG). The RSG size was prepared by soaking Lefranc & Bourgeois' rabbit skin glue granules in water overnight and then heating the mixture to 60ºC. Prior to casting, the sized canvases were dried for seven days at ambient conditions in the microscopy laboratory of the Art Conservation Program at Queen's University. The gesso samples consisted of 67% $CaCO_3$ (with a particle size of 0.07 µm) bound in either 10% w/w

Lefranc & Bourgeois rabbit skin glue (in water) or 25 % (w/v) Aquazol 200. The samples were cast on the sized canvas in wells of 3MR electrical tape (29 cm x 8 cm) to a dried thickness of approximately 710 microns. The castings were created by drawing down the wet material with the long side of a microscope slide. Once the casting formed a surface film, the tape was removed and the casting dried for at least one week at ambient conditions.

Collecting and Processing

Each sample subjected to reflectance transformation imaging had a sample size and an imaging size was 7 cm x 6 cm. The castings were segmented into three sections, allowing for each casting to produce three different sets of image, from which three different RTI images were rendered. These RTI images were then all processed in the same manner. The raw series of images was reconstructed using RTI builder (Fig.1) and examined with RTIviewer. A snapshot of the static multi-light image of each sample was created using RTIviewer (Fig. 2a) and then loaded into ImageJ. The images were then converted to an 8-bit grey scale image (Fig. 2b), following which several different mathematical functions were applied.

Figure 1 Reconstruction of RTI images in RTI builder.

a) b)

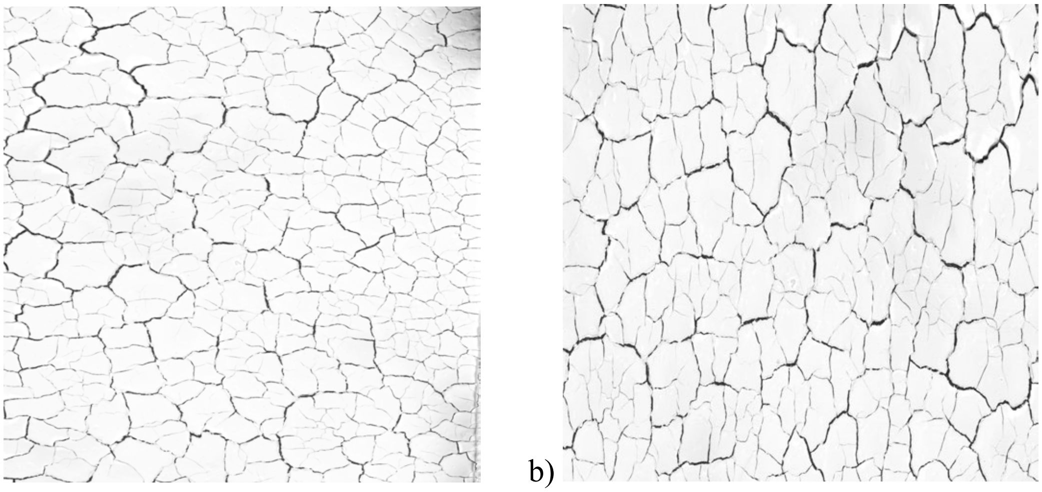


Figure 2 A snapshot of a static multi-light image (a) and a 8-bit grey scale image.

The first of these was used to change the greyscale image into a binary image. Many supplementary functions and functions available within ImageJ can convert a greyscale image (Fig. 2b) to a binary image. The built-in ImageJ binarization functions were applied to the images; however, this process resulted in an unsatisfactory binarization (e.g. sections of the crack pattern being selected as part of the casting). Several supplementary functions or plugins were then applied to the images. The function that produced the best results was the Otsu thresholding method, an adaptive thresholding method that was applied to the images or raw data. The aim of the Otsu thresholding method is to find the threshold value where the sum of values representing the crack spread and the gesso casting spread is at its minimum. The algorithm assumes that the image is composed of two basic constituents: the crack pattern and the casting. An optimal threshold value is computed that minimizes the weighted within class variance of these two constituents. Application of the Otsu thresholding method made it possible to distinguish between the gesso casting and the crack pattern, resulting in a binary image of the crack pattern (Fig. 3).

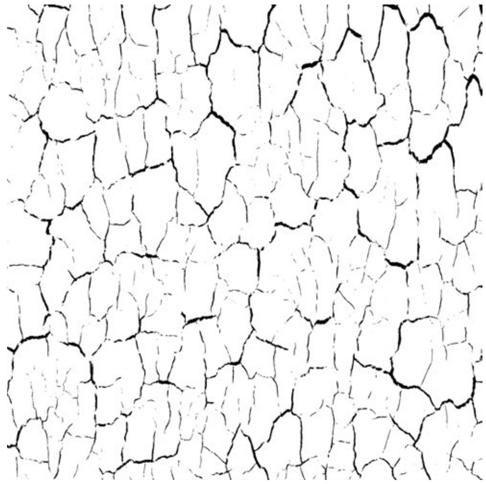


Figure 3 A binary image after using the Otsu thresholding method.

The Skeletonize function of ImageJ was then used to convert the Otsu image into a "skeleton image", resulting in the cracks themselves having a uniform thickness. The skeletonized images were then analyzed using the Analyze Skeleton function of ImageJ. The function produced information about junctions and crack length, as well as giving a tagged image (Fig 4).

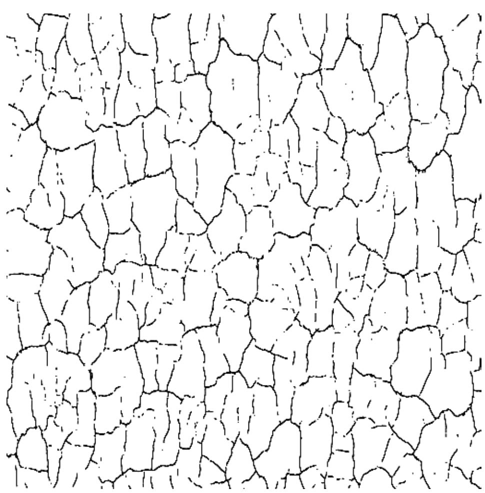


Figure 4 Skeletonized image.

Analysis of Skeletonized Output: Directionality and Islands

To determine the directionality of the cracks within the crack pattern, OrientationJ, a plugin feature of ImageJ, was used. This function produced a histogram (Fig. 5) and a hue saturation brightness (HSB) colour map (Fig. 6).

For the histogram displayed in Figure 5, the majority of the cracks were aligned with the warp and weft as the peaks located at 0 degrees displayed the greatest intensity. The second largest set of peaks was located at -45 and 45 degrees, which means that the second largest population of cracks were aligned 45 degrees from the weft and warp.

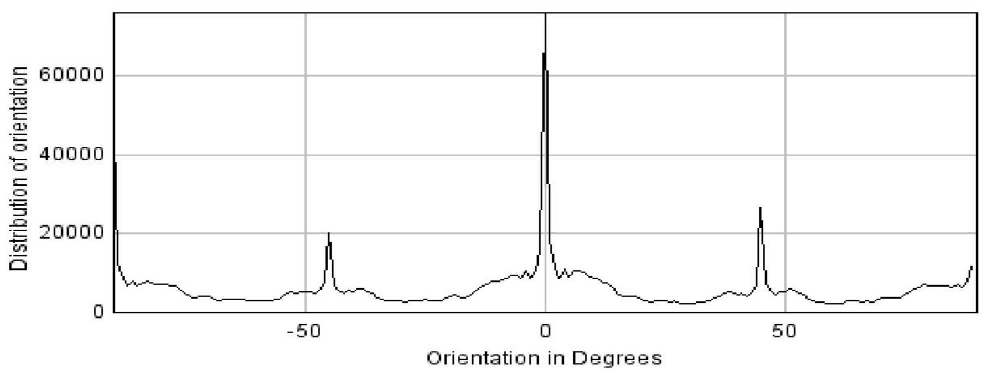


Figure 5 Histogram output from OrientationJ.

A HSB colour map is another way to visualize the directionality of the crack pattern. Knowing the orientation of the canvas weave in reference to the image capturing process allows us to assign directionality to the HSB colour map. In Figure 6, the weft of canvas is the horizontal plane of this image and each colour in the HSB colour map represents a different angle, which can be determined by using the colour key. As the histogram in Figure 5 and this HSB colour map (Fig. 6) are outputs from the same skeletonized image, they describe the same characteristics. The majority of the cracks are aligned with the warp and weft, as most of the cracks displayed in Figure 6 are light blue or pink/red, which represent 0 degrees and 90 degrees.

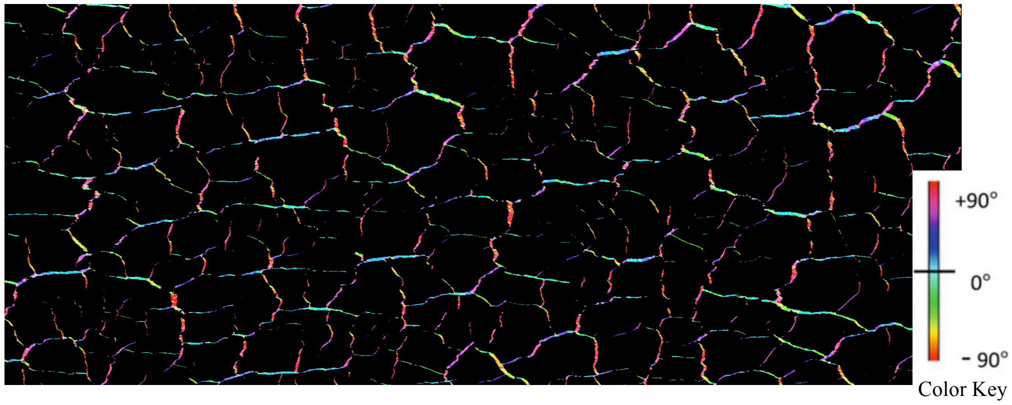
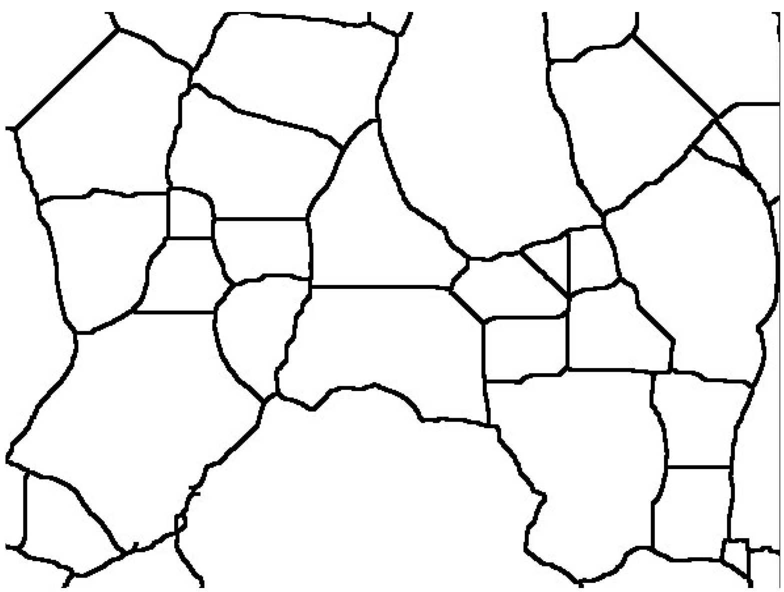


Figure 6 Hue saturation brightness (HSB) colour map from OrientationJ with colour key.

Islands

A segmentation feature called watersheding was used to produce information about the individual islands within the samples (Fig. 7a). After this feature was applied, the islands became segmented and were measured using a feature called Particle Analyzer which treated each individual island independently and produced a location map for each (Fig. 7b). The numbers found in this map then coincided with a results table which displayed the area, mean, standard deviation, and x, y coordinates of the specific island on the map.



a)

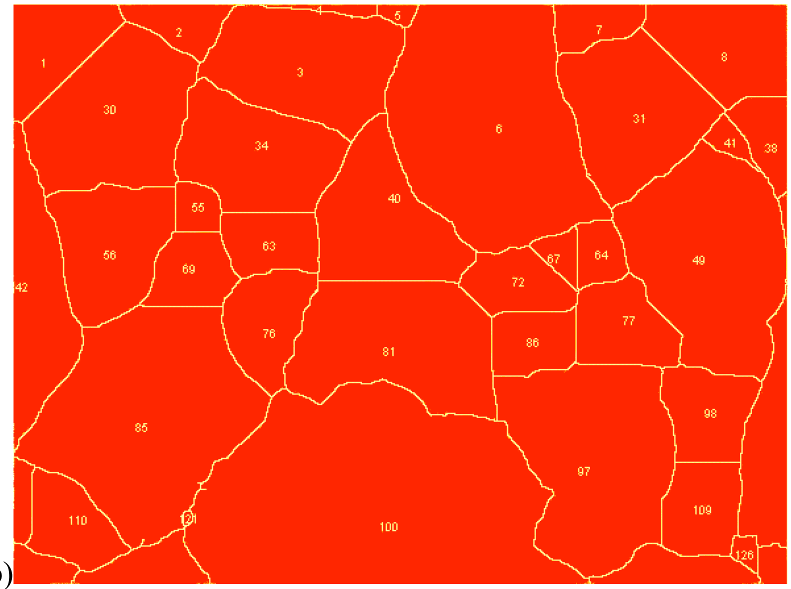
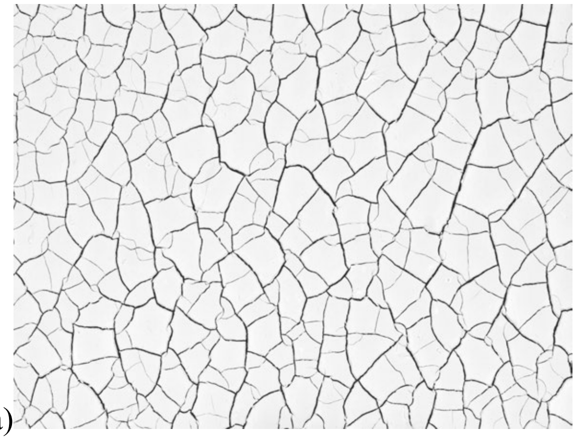
b) 

Figure 7 Section of the casting after watersheding (a) and after the Particle Analyzer was applied to the image (b).

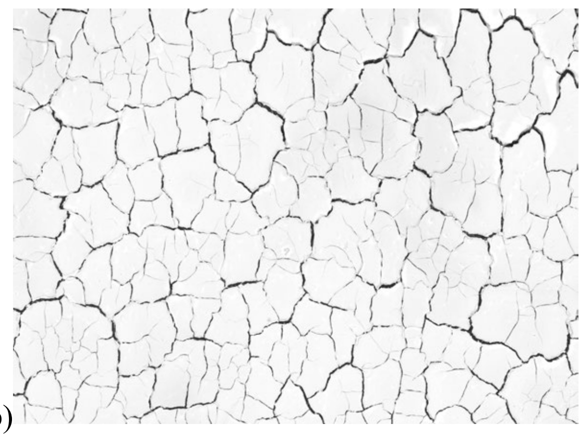
Results

Preliminary gesso data

The computational findings of the RSG-based samples were rather different from those of the Aquazol-based samples; however, these findings were expected, as the cracking pattern of these gessoes are visually different (Fig. 8 and b). From the calculations, the RSG-based samples had 1.4 times more cracks per area and 1.2 times the triple points per area as the Aquazol samples, while the Aquazol samples had 1.8 times the quadruple points per area and 1.3 times more junctions per crack length as the RSG-based samples.



a)



b)

Figure 8 Snapshots of a static multi-light image of RSG-based gesso sample (a) and Aquazol-based gesso sample (b).

Preliminary Island Data

The typical island size found in RSG was 1.39 times larger than in Aquazol. They have about the same number of total islands, with Aquazol having 1.1 times more islands than RSG. The following histogram (Fig. 9) shows the frequency of each island size. Aquazol is more highly populated with small islands than RSG. There are also large islands in the Aquazol casting, which are not found in the RSG casting.

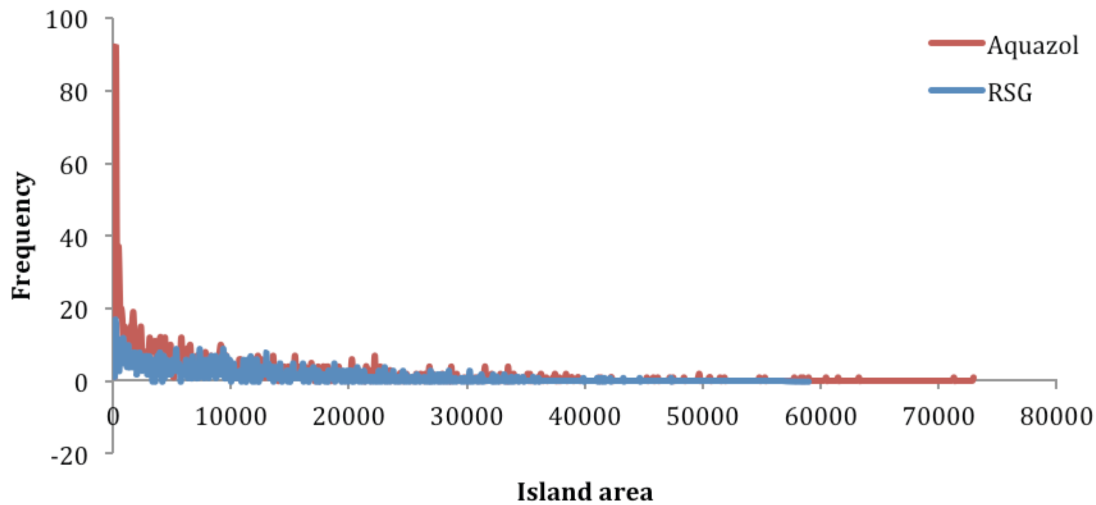


Figure 9 Histograms of Aquazol-based gesso sample and RSG-based gesso samples.

Preliminary Directional Data

Figure 10 displays the relative populations of crack angles found within the gesso samples, where 0° was assigned to the weft of the canvas and 90° was assigned to the warp of the canvas. The cracks found within the RSG-based and Aquazol-based samples are aligned with the weft of the canvas to almost the same degree. This is exhibited by the population peaks located at 0° being almost identical in intensity. In addition, the cracks in the Aquazol-based samples are more aligned with the warp than the cracks in the RSG-based samples, as the relative population of the Aquazol-based samples displayed a higher intensity at 90° than the RSG-based samples.

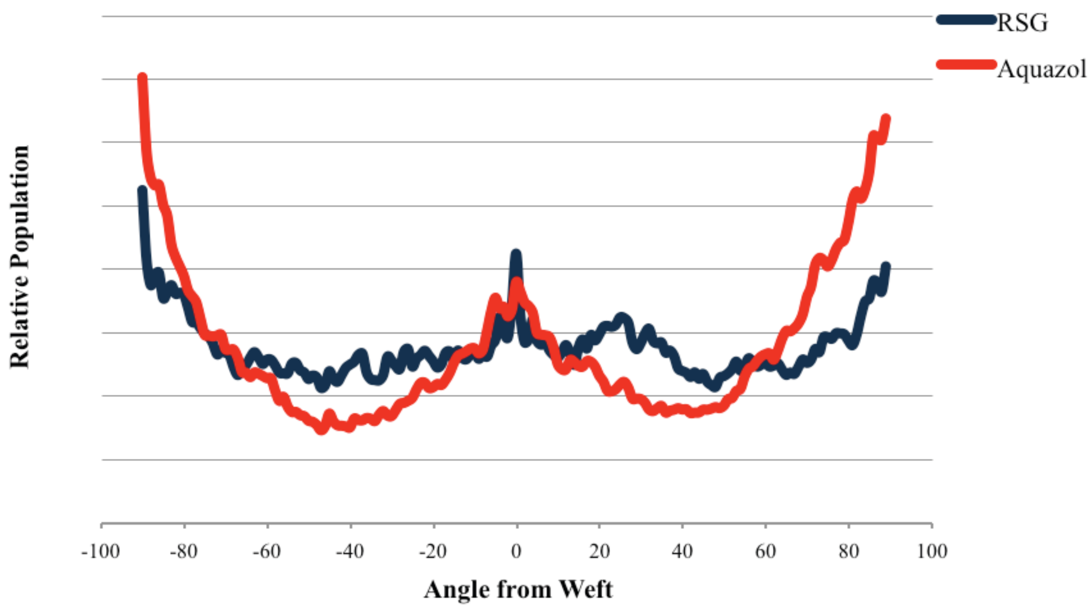


Figure 10 Relative populations of crack angles found within Aquazol-based gesso sample and RSG-based gesso sample.

Conclusions

Use of RTI imaging and ImageJ quantified physical characteristics of about the craquelure of two calcium carbonate gessoes. The RSG-based samples displayed a higher crack density than the Aquazol samples. In addition, the RSG samples were more likely to have Y-shaped cracks, while the Aquazol samples were more likely to have four cracks meeting at a point and the cracks were more likely to have branches. The typical island was larger for the RSG-based samples, although the Aquazol casting displayed larger islands. Even though the cracking patterns of these two samples appeared to be different, the Aquazol cracking pattern was composed of slightly more islands than the pattern in the RSG-based samples.

The information obtained from this technique could be used in conservation condition reports; for example, RTI imaging could document distortions or degradation products caused by environmental change. This could include dimensional changes or flaking of paint layers. Objective information could be gained about the effects of treatments before and after consolidation or infilling. In addition, this process could be carried out on three-dimensional works of art including paintings, sculptures, and works on paper. All of the information gained from this documentation process could be shared electronically, allowing the object to be accessible to those who might not be able to visit the object physically. ImageJ, the image-processing program used here, is freely available and can be downloaded very easily.

Bibliography

1. "Process: RTIBuilder Download." Cultural Heritage Imaging. http://culturalheritageimaging.org/What_We_Offer/Downloads/Process/index.html (accessed August 2012)

2. "View: RTIViewer Download New! Version 1.1." Cultural Heritage Imaging. http://culturalheritageimaging.org/What_We_Offer/Downloads/View/index.html (accessed August 2012)

3. "Reflectance Transformation Imaging (RTI)." Cultural Heritage Imaging. http://culturalheritageimaging.org/Technologies/RTI/ (accessed August 2012)

4. "More Examples of Reflectance Transformation Imaging." Cultural Heritage Imaging. http://culturalheritageimaging.org/Technologies/RTI/more_rti_examples.html (accessed August 2012)

5. "Squeeze Imaging Project." Smithsonian Institution. http://www.asia.si.edu/research/squeezeproject/default.asp (accessed August 2012)

6. Willen, C. "Preserving and Sharing Ancient Treasures With Cultural Heritage Imaging Technology." Cultural Heritage Imaging. http://culturalheritageimaging.org/What_We_Do/Projects/cher/index.html (accessed August 2012)

7. Mudge, M., T. Malzbender, C. Schroer and M. Lum. 2006. "New Reflection Transformation Imaging Methods for Rock Art and Multiple-Viewpoint Display." In: M. Ioannides, D. Arnold, F. Niccolucci and K. Mania (eds.), *The 7th International Symposium in Virtual Reality, Archaeology and Cultural Heritage (VAST 2006).* Eurographics Association, pp. 195-200.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.73.754&rep=rep1&type=pdf

8. Earl, G., Basford, P. J., Bischoff, A. S., Bowman, A., Crowther, C., Dahl, J., Hodgson, M., Martinez, K., Isaksen, L., Pagi, H., Piquette, K. E. and Kotoula, E. 2011. Reflectance transformation imaging systems for ancient documentary artefacts. In, Bowen , Jonathan P., Dunn, Stuart and Ng , Kia (eds.) *EVA London 2011: Electronic Visualisation and the Arts. EVA 2011: Electronic Visualisation and the Arts* , BCS. http://eprints.soton.ac.uk/204531/1/ewic_ev11_s8paper3.pdf

9. Earl, Graeme, G. Beale, K. Martinez, H. Pagi. 2010. "Polynomial texture mapping and related imaging technologies for the recording, analysis and presentation of archaeological materials." *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, v. 38, Part 5 Commission V Symposium, Newcastle upon Tyne, UK. 2010. http://www.isprs.org/proceedings/XXXVIII/part5/papers/227.pdf (accessed August 2012).

10. Stout, G.L.1977. "A Trial Index of Laminal Disruption." Journal of the American Institute for Conservation 17(1), 3, p.22

11. CCI Notes 10/11 Condition Reporting - Paintings Part III: Glossary of Terms. http://www.cci-icc.gc.ca/publications/notes/10-11-eng.aspx Date Modified: 2013-7-24(accessed August 2012).

12. Bucklow, S. 1998. *A Stylometric Analysis of Craquelure.* Computers and Humanities 31(6), p. 503–521.