# COMPUTATIONAL ART HISTORY

# 2012-13 Research Activity Report

C. Richard Johnson, Jr. :: Cornell University :: January 7, 2014

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*Summary* :: In 2005, Professor Johnson began shifting his scholarship to the application of signal processing to address issues in art history. In 2007, he founded the Thread Count Automation Project to develop and exploit signal processing algorithms to estimate the thread count of the canvas of Old Master paintings from scanned x-radiographs. This effort developed a new method for identifying canvas rollmates based on matching striped patterns in the thread counts of canvas from the same roll. In 2010, Professor Johnson initiated the Historic Photographic Paper Classification (HPPC) challenge in cooperation with the Museum of Modern Art. This work has established that a variety of texture classification schemes can use raking light photomicrographs to identify papers with the same meta-data, i.e. manufacturer, surface finish, brand, and date of manufacture. Professor Johnson launched the Chain Line Pattern (CLiP) Matching Project with the Morgan Library & Museum in 2012, with the Rijksmuseum and the Metropolitan Museum of Art joining this effort in 2013. This research attempts to identify pre-1750 laid papers made on the same mold. These various signal processing procedures developed for identifying fine art support materials are having an impact on dating, attribution, and physical characterization of works of art.

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### Computational Art History

Mimicking the definition of computational biology from Wikipedia:

> Computational art history involves the development and application of data-analytical and theoretical methods, mathematical modeling and computational simulation techniques to the study of art history.

Fundamentally, when an art historian derives needed information solely from examination of an image of the art object signal/image processing should be able to assist and expand the scholary reach of the art historian.

### Thread Count Automation Project (TCAP)

For example, thread counting from x-radiographs of paintings on canvas is forensic data gathered by art historians as an indicator of whether two paintings may be on canvas originally from the same roll. If two paintings are deemed to be from the same canvas roll this can be used, in combination with knowledge of the artist's practice, to support conclusions regarding the dating and authentication of the paintings. Prior to 2007, the approach was to average the manually counted numbers of threads/cm in several spots across a painting's canvas with sufficiently different average counts for two canvases indicating they could not be from the same roll. If the counts were the same, this only established the possibility that the two canvases might be from the same original roll.

In 2007, Professor Johnson confirmed that thread counting for canvas with a sufficiently regular weave could be tackled via Fourier analysis with such a data-analytical method readily producing thread counts at spots covering the entire painting. Due to the mechanics of the loom weaving process such comprehensive automated thread counting revealed stripes of similar counts in the two (nearly) orthogonal thread directions in a simple weave. The profiles of these stripes provide "fingerprints" that are far more conclusive in identifying rollmates than a painting-wide average thread count.

In keeping with information gleaned from the letters of Vincent van Gogh indicating that he commonly used canvas he cut from rolls sent to him by his brother, the initial results were the identification of rollmates among approximately 60% of Vincent's paintings. Acquiring access to the image data needed for a broad study of Vincent's paintings from dozens of museums – even with the support of the Van Gogh Museum – proved to be an extremely time consuming task for Professor Johnson. As the number of van Gogh paintings examined exceeded 400 the groundbreaking impact of this approach became apparent. As described in [1], this new forensic data has provided insights resolving numerous dating and authentication issues critical to art historical analysis of the oeuvre of Vincent van Gogh.

This approach has proven applicable to a wide range of Old Master European paintings from the 16th through the early 20th centuries. As reported in [2], a weave match proved to be a key piece of evidence in resolving a long-standing controversy regarding the identification of the painting of a royal courtier by Velázquez made at the same time and place as a portrait of the king. A weave match hunt undertaken among the x-radiographss of most (though not all) of Vermeer's paintings on canvas discovered three matches with art historical implications, as reported in [3]. More recently, [4] uncovered a weave match among three paintings by Nicholas Poussin, thereby establishing them as from the same roll of canvas. Interestingly, this insight could lead to a major re-evaluation of the authenticity of these three paintings as one is universally considered an autograph work by Poussin while another is considered to be by a later imitator.

### Historic Photographic Paper Classification (HPPC)

Another task where art historians study images in order to extract physical information that can identify the support material is in the classification of texture of historic photographic paper. As silver gelatin photographic paper was manufactured with different surface texture and selected for use by photographers for the different effects achieved in photographs printed on these different textures, classification of historic photographic papers of uncertain origin has been based on surface texture ascertained from the study of images, such as raking light photomicrographs, that reveal surface texture. Recently, a multi-year study coordinated by Professor Johnson reported in [5] verified the potential for meta-data classification based on automated texture classification algorithms comparing raking light photomicrographs against a library of such images of paper of known provenance. This was followed by another paper [6] extending this approach to the classification of more modern inkjet papers.

### Chain Line Pattern (CLiP) Matching

Laid papers manufactured by scooping pulp with handmade molds containing wire screens that allowed the water to drain leaving a sheet of paper was the standard mode of producing paper in the Occident until the mid-18th century. As the water drains and the pulp settles on the screen, the wires in the screen leave indentations in the paper. The resulting variations in paper thickness can be readily viewed, for example, from beta-radiographs. As these molds are handmade the revealed patterns of the wire screens are presumed to be distinguishable from mold to mold.

The prevailing method for identifying laid papers made from the same mold relies on the use of watermarks that were woven into the wire screens. However, as each mold has only one watermark woven into the screen and the produced papers are often cut into smaller sizes before being used for prints, drawings, and manuscripts, only a small fraction (e.g. approximately only one-third of the prints of Rembrandt) have identifiable watermarks (or watermark fragments). The method proposed by Professor Johnson and first announced in [7] was to rely instead on the spacings and relative angles of the chain lines in the screen patterns. An effort is underway to automate this approach and test its validity on the prints of Rembrandt van Rijn. This chain line pattern matching activity is likely to dominate Professor Johnson's efforts in computational art history in 2014.

## Selected Publications


1. L. van Tilborgh, T. Meedendorp, E. Hendriks, D. H. Johnson, C. R. Johnson, Jr., and R. G. Erdmann, "Weave Matching and Dating of Van Gogh's Paintings: An Interdisciplinary Approach," *The Burlington Magazine*, vol. CLIV, pp. 112-122, February 2012.

2. P. Perez d'Ors, C. R. Johnson, Jr., and D. H. Johnson, "Velázquez in Fraga: a New Hypothesis about the Portraits of El Primo and Philip IV," *The Burlington Magazine*, vol. CLIV, pp. 620-625, September 2012.

3. W. Liedtke, C. R. Johnson, Jr., and D. H. Johnson, "Canvas Matches in Vermeer: A Case Study in the Computer Analysis of Fabric Supports," *Metropolitan Museum Journal*, vol. 47, pp. 99-106, 2012.

4. R. G. Erdmann, C. R. Johnson, Jr., M. Schafer, J. Twilley, and T. Sawyer, "Reuniting Poussin's Bacchanals Painted for Cardinal Richelieu through Qunatitative Canvas Weave Analysis," *41st An-*

*nual Meeting of American Institute for Conservation of Historic and Artistic Works*, Indianapolis, IN, May 2013.

5. C. R. Johnson, Jr., P. Messier, W. A. Sethares, A. G. Klein, C. Brown, A. H. Do, P. Klausmeyer, P. Abry, S. Jaffard, H. Wendt, N. Pustelnik, N. van Noord, L. van der Matten, E. Postma, J. Coddington, L. A. Daffner, H. Marata, H. Wilhelm, S. Wood, and M. Messier, "Pursuing Automated Classification of Historic Photographic Papers from Raking Light Photomicrographs," submitted to the *Journal of the American Institute for Conservation*, May 2013.

6. P. Messier, C. R. Johnson, Jr., H. Wilhelm, W. A. Sethares, A. G. Klein, P. Abry, S. Jaffard, H. Wendt, S. Roux, N. Pustelnik, N. van Noord, L. van der Maaten, and E. Postma, "Automated Surface Texture Classification of Inkjet and Photographic Media," *29th International Conference on Digital Printing Technologies*, October 2013.

7. C. R. Johnson, Jr., W. A. Sethares, M. H. Ellis, R. Snyder, E. Hinterding, I. van Leeuwen, A. Wallert, D. Christoforou, and J.van der Lubbe, "Laid Paper Mold-Mate Identification via Chain Line Pattern (CLiP) Matching of Beta-Radiographs of Rembrandt's Etchings," *New Directions in the Study of Rembrandt and His Circle*, July 2013.

Reprints of these publications and further information about the research of Professor Johnson are available from http://people.ece.cornell.edu/johnson/

## Talks

- "Weave Match Hunting: An Application of Signal Processing to Painting Analysis", Signal Processing and Speech Communication Laboratory, Graz University of Technology, Graz, Austria, April 10, 2012, International Conference on Systems, Signals and Image Processing Keynote, Vienna, Austria, April 12, 2012, and Stichting Restauratie Atelier Limburg, Maastricht, the Netherlands, May 24, 2012.

- “Weave Match Hunting: Computational Humanities in Art History”, Art Conservation Department, Buffalo State SUNY, May 18, 2012.
- “Computational Art History: Weave Match Hunting among the Paintings of van Gogh, Vermeer, Velázquez, and Poussin”, Conservation Center, New York University, September 27, 2012, Art+ Lecture Series, Duke University, October 25, 2012, and Center for Signal and Image Processing, Georgia Tech, October 26, 2012.
- “Computational Art History: Signal Processing Applied to Thread Counting and Weave Match Hunting”, Mellon Research Initiative Workshop, Institute of Fine Arts, New York University, December 1, 2012.
- “Thread Counting and Rollmate Identification: A Short Course”, Art Conservation Department, Buffalo State SUNY, March 8, 2013, Stichting Restauratie Atelier Limburg, Maastricht, the Netherlands, April 11, 2013 and October 16, 2013, and Program in Art Conservation, Winterthur/University of Delaware, November 2, 2013.
- “Computational Art History: Weave Match Hunting Among the Paintings of van Gogh, Vermeer, and Poussin”, Johnson Art Museum, Cornell University, May 2, 2013.
- “Computational Art History: Weave Match Hunting Among the Paintings of van Gogh, Vermeer, Velázquez, and Poussin”, Program in Art Conservation, Winterthur/University of Delaware, May 8, 2013, ExCITE Center, Drexel University, May 9, 2013 and Cologne Institute of Conservation Sciences, Köln, Germany, June 21, 2013.
- “Counting Van Gogh and Computational Art History”, Symposium on Van Gogh’s Studio Practice in Context, Van Gogh Museum, Amsterdam, the Netherlands, June 25, 2013.
- “Chain Line Pattern Matching for Mold-Mates from Beta-Radiographs”, New Directions in the Study of Rembrandt and His Circle, Herstmonceux Castle, East Sussex, United Kingdom, July 19, 2013.

- “Weave Match Hunting and Computational Art History”, New Directions in the Study of Rembrandt and His Circle, Herstmonceux Castle, East Sussex, United Kingdom, July 20, 2013.
- “Toward Automated Classification of Historic Papers”, Metropolitan Museum of Art, September 25, 2013.
- “Emerging Technologies in Art Historical Dating and Attribution: Identifying Patterns in the Supports of Works by Bouts, Dürer, Poussin, Velázquez, Rembrandt, Vermeer, and Van Gogh”, Otto Naumann Gallery, September 30, 2013.
- “Chain Line Pattern (CLiP) Matching of Laid Papers”, Conservation Center, New York University, November 19, 2013 and The Morgan Library & Museum, November 20, 2013.
- “Computational Art History: Three Emerging Projects”, Polytechnic Institute of New York University, December 5, 2013.

Professor Johnson is to present a plenary talk (“Signal Processing in Computational Art History”) on Tuesday, May 6, 2014, at IEEE ICASSP 2014 (abstract available at www.icassp2014.org/plenary_speakers.html).