THREAD COUNT REPORT

Waterloo Bridge, Sunlight Effect
Claude Monet
1903
(W1586 / 1933.1163)

from the Art Institute of Chicago

Presented by the
Thread Count Automation Project

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Acknowledgments: The thread counting software arose from a collaboration between the van Gogh Museum (Amsterdam) and the Thread Count Automation Project initiated by Professor C. Richard Johnson, Jr. in the School of Electrical and Computer Engineering at Cornell University. The x-ray "stitching" algorithm, developed by Professor Robert G. Erdmann (University of Arizona), uses a multi-scale feature-point detection and edge-blending algorithm described in "Whole-Painting Canvas Analysis Using High- and Low-Level Features," *ICASSP*, May 2011. The thread count calculations were performed by Professor Don Johnson (Rice University) using the technique described in Johnson et al., "A Thread Counting Algorithm for Art Forensics," *Proc. 13th IEEE DSP Workshop*, January 2009. The software used here has been in development since 2007 in a collaboration among researchers B. Sethares, R. Arora, and H. Lee at the University of Wisconsin, A. Klein at Worcester Polytechnic Institute, D. Johnson at Rice University, and R. Johnson and J. Ng at Cornell University. A student team at Cornell (J. Ng, C. Cheung, M. Cho, P. Kung, S. Lok, B. Stubler, M. Wu, L. Zhang) plus a "corresponding" student at WPI (I. Ozil) are responsible for testing numerous early versions of the software suite and performing the manual counts used to assess the candidate thread counting algorithms. For more information on the software used, contact Professor Rick Johnson at `johnson@ece.cornell.edu` or Professor Don Johnson at `dhj@rice.edu`. The x-rays provided for algorithm development were selected by Dr. Ella Hendriks of the van Gogh Museum and digitized by Frans Stive of the van Gogh Museum by scanning them into 16-bit greyscale tiff files at high resolution (greater than 300 dpi, typically 600 dpi).

Summary

This report provides the canvas weave densities and local thread angle variations of *Waterloo Bridge, Sunlight Effect* (W1586 / 1933.1163) by Claude Monet held in the collection of the Art Institute of Chicago. Automatic counts were made from high resolution digital scans of x-rays (600 dpi, 1:1 with painting surface; 8-bit greyscale). These x-rays, at sufficient enlargement, expose the canvas weave to be in the "plain" category. Software automates the process of determining, across the entire scanned x-ray, the thread count of the canvas weave pattern in two directions (nearly vertical and nearly horizontal in the x-ray) and the angles of these threads referenced to true vertical and horizontal respectively. The thread-count processing software revealed the average (avg) and standard deviation (σ) of the thread counts and angles for the horizontal and vertical threads for the entire painting to be

W1586	avg	σ
horizontal thread density (th/cm)	**14.8**	0.4
vertical thread density (th/cm)	**14.8**	0.3
horizontal thread angle (degrees)	**-0.7**	1.1
vertical thread angle (degrees)	**0.4**	1.3

The warp threads were determined by visual examination of the weave and angle maps to correspond to the vertical threads. From the x-rays, the weave was determined to be a plain (rectilinear) pattern.

This report provides a horizontal thread count deviation map, a vertical thread count deviation map, a horizontal thread angle map, a vertical thread angle map, and histograms of horizontal and vertical thread counts. A table of contents occurs on page 3.

Introduction

This report provides a series of figures representing visualizations of various thread count and angle data for *Waterloo Bridge, Sunlight Effect*. All x-ray scans used in this report were provided at 600 dpi. The scans were then cropped in Photoshop by Professor Don Johnson (Rice University) to exclude portions of the x-ray outside the canvas. When scans included a portion of the canvas's front edge, it was used to align the corresponding edge of the cropped image, thereby enabling a consistent orientation of the cropped images with respect to the painting. A composite x-ray of the entire painting was computed from individual scans by Professor Robert Erdmann (University of Arizona). Using this composite as the input, the thread count calculations employed the following protocol.

- The DENSITY MAPS record the average thread densities (in threads/cm) computed in overlapping 1.25 cm squares on 0.25 cm centers for each x-ray. The density at each location is indicated by a color. Separate maps are provided for (near) horizontal and (near) vertical threads. X-rays of canvas taken from the same roll should have a very close (within tenths of a thread/cm) match of average densities of threads in the warp direction and a close match (within ±1 thread/cm) in the weft direction. The warp- and weft-thread directions were determined subjectively. Warp-direction weave patterns have thread counts that tend to have a smaller variance, to change little in the thread direction and to change much more in the perpendicular direction. Weft-direction weave patterns are less consistent in the thread direction and tend to have thread counts that change slowly in the perpendicular direction.
- The THREAD ANGLE MAPS indicate with color the values of the average thread angle (relative to horizontal and vertical alignment of the x-ray) in the 1.25 cm squares examined to compose the weave maps. Separate maps are provided for the (near) horizontal and (near) vertical threads. These angle maps vividly display cusping when present by a succesion of color patterns alternating gracefully between the extremes of the colorbar (between red and blue then back again).

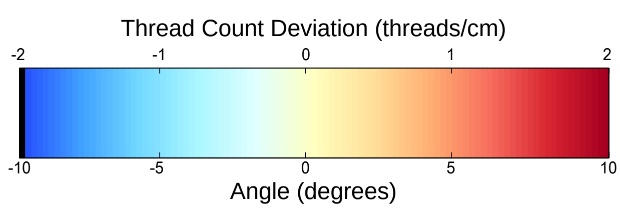

Illustration of the calibrated colorbar for both the weave deviation maps and the weave angle maps.

- The HISTOGRAM plots the number of evaluation squares having average densities within each range increment (of 0.1 th/cm) along the *x*-axis. This plot is useful for visualizing the distribution of the thread densities. Canvases from the same roll should have quite similar histograms in both directions. Often, the threads in the warp direction show less variability, i.e. a narrower distribution, in their count than the weft threads.

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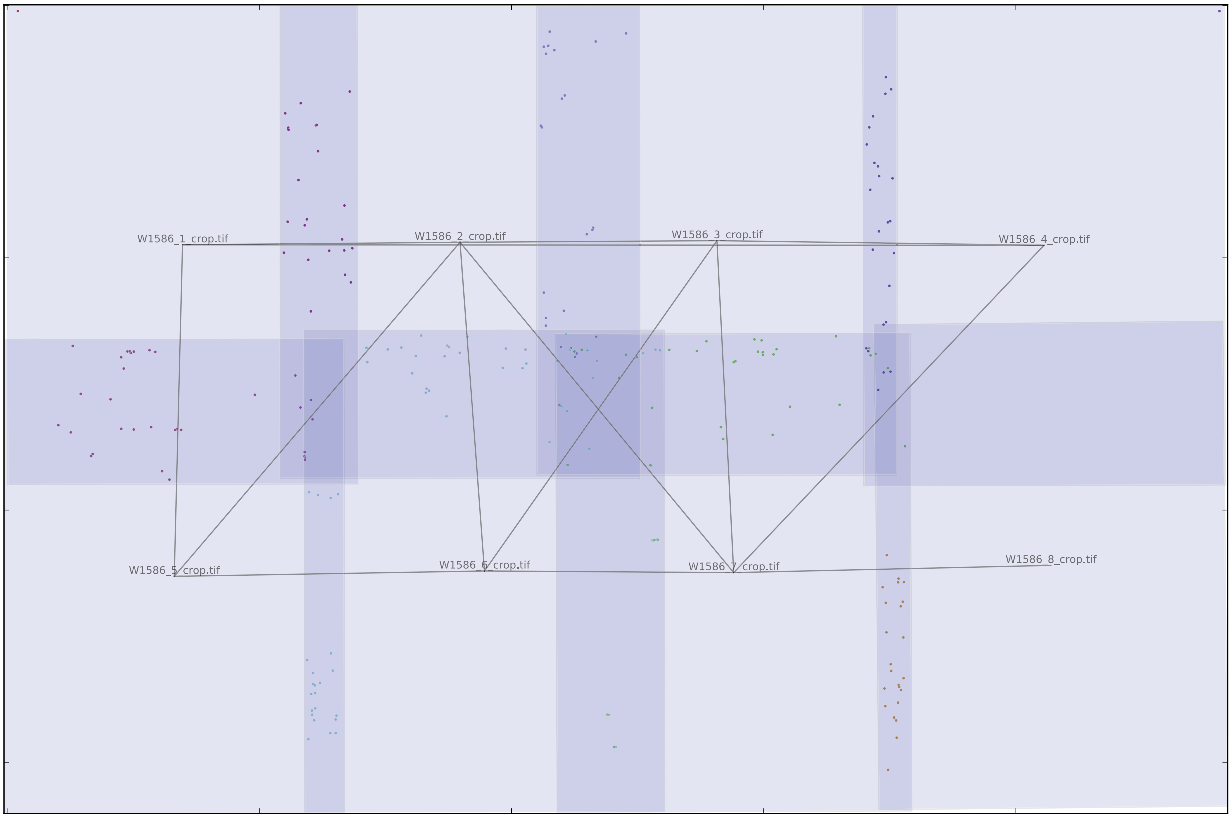
Waterloo Bridge, Sunlight Effect (W1586 / 1933.1163)

[65.7 × 101.0 cm, 01.01.1903-31.12.1903, Art Institute of Chicago]

X-Ray Layout

The following diagram depicts x-ray locations with respect to the painting and what rotations/translations were used in creating a composite x-ray. The dots represent features used in creating the composite; lines join x-rays sharing features. X-ray size is to scale, as is the outline of the painting.



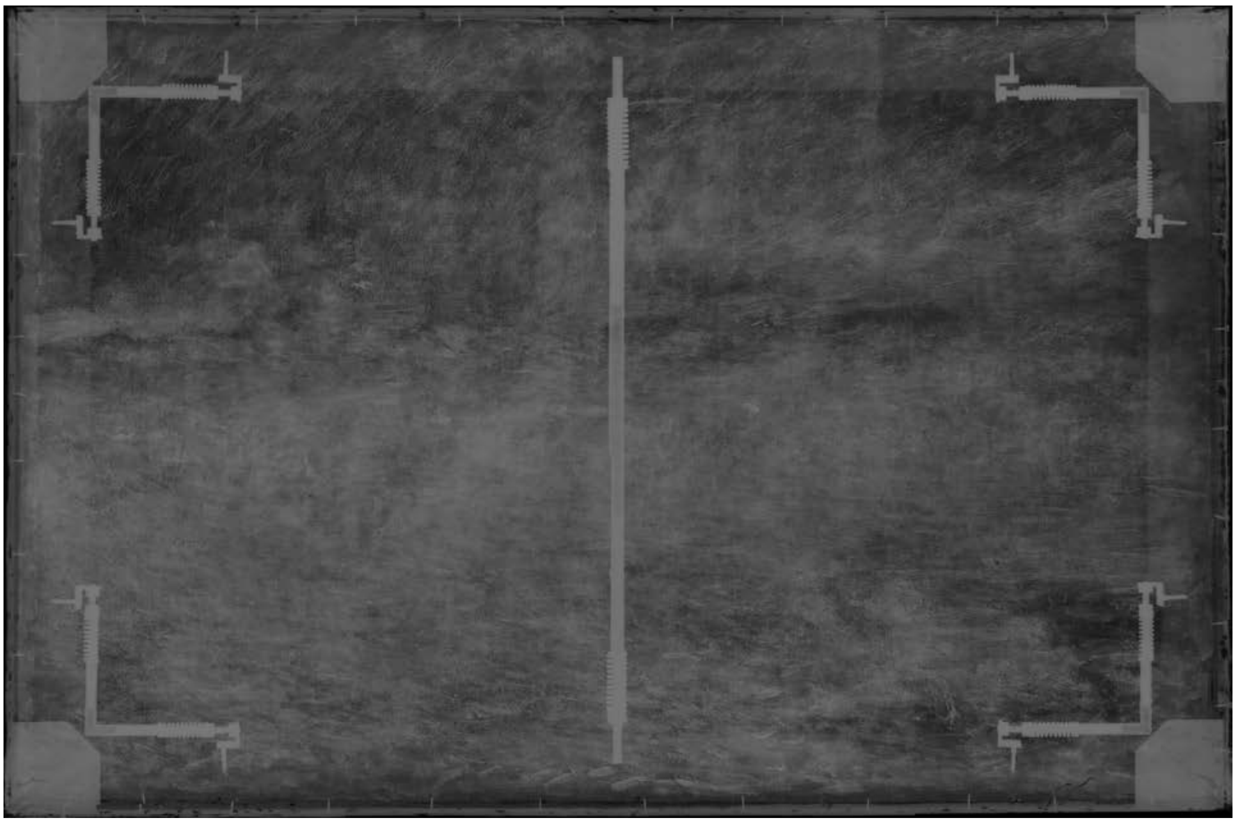


Figure 1: Composite x-ray created by Professor Erdmann's stitching software.

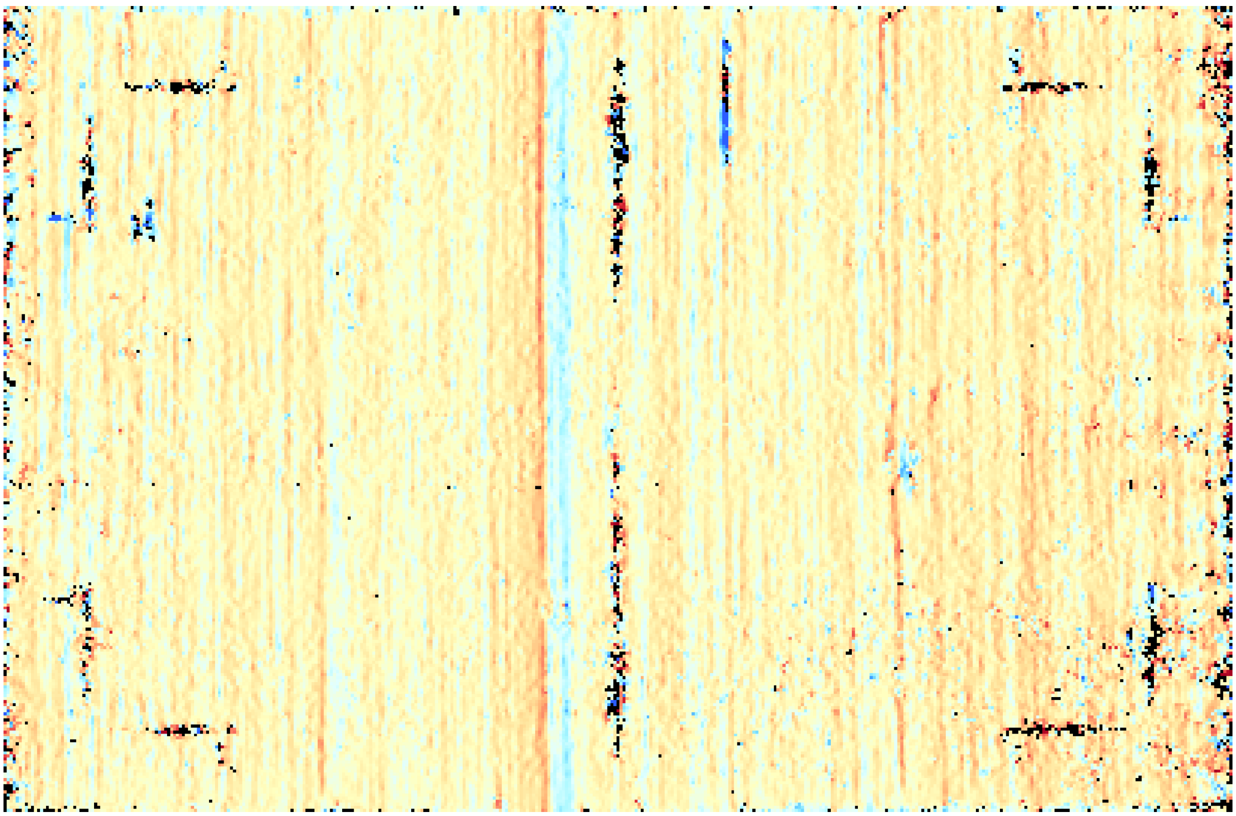


Figure 2: Vertical (presumed warp) thread count deviation map for the entire painting.

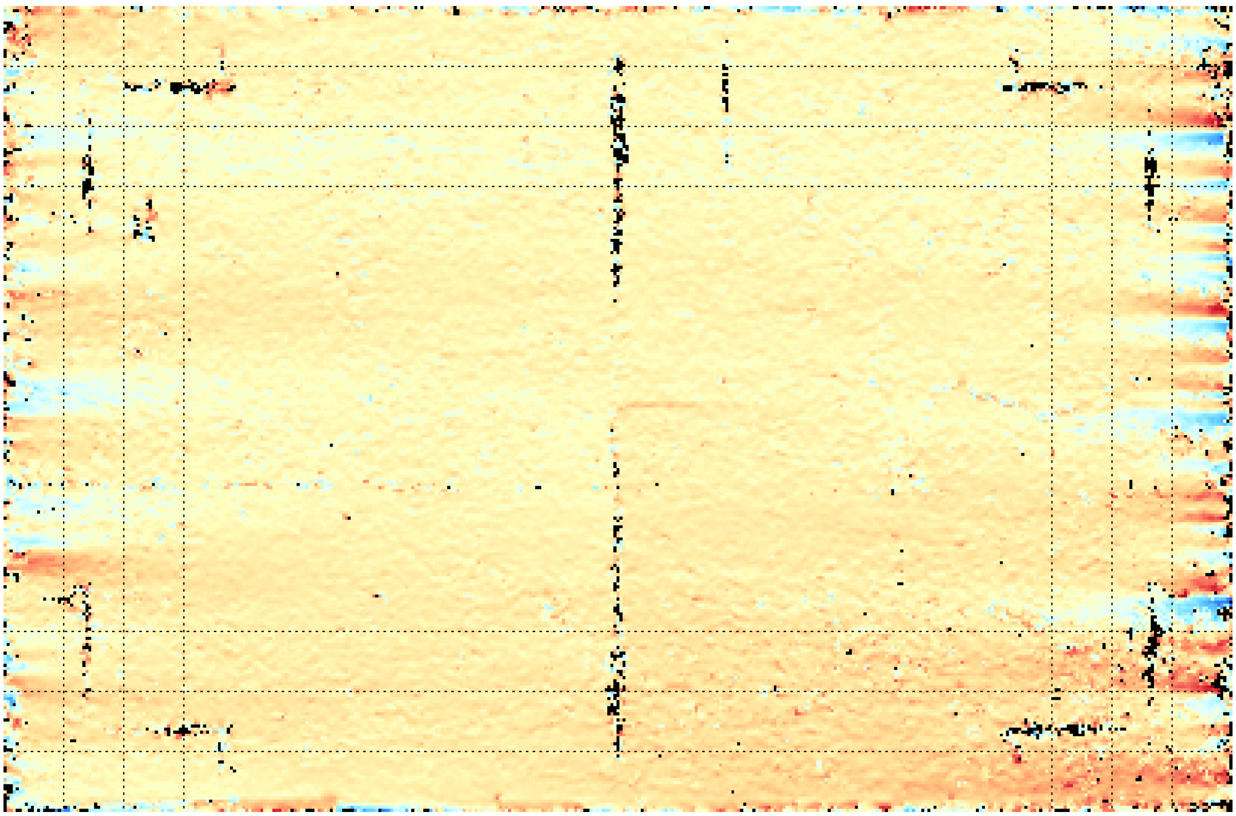


Figure 3: Vertical (presumed warp) thread angle map for the entire painting. Horizontal and vertical dashed lines are separated by 5 cm and can be used to judge cusping depth and separation.

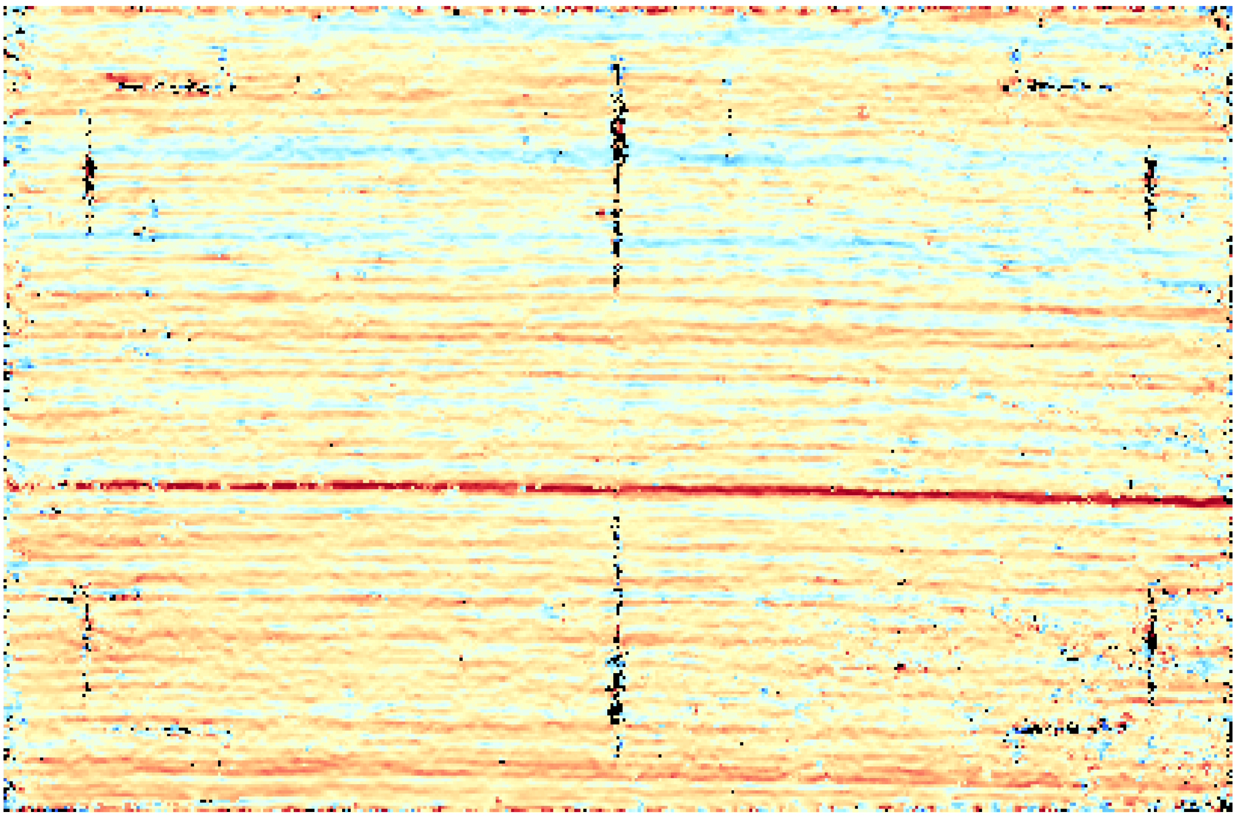


Figure 4: Horizontal (presumed weft) thread count deviation map for the entire painting.

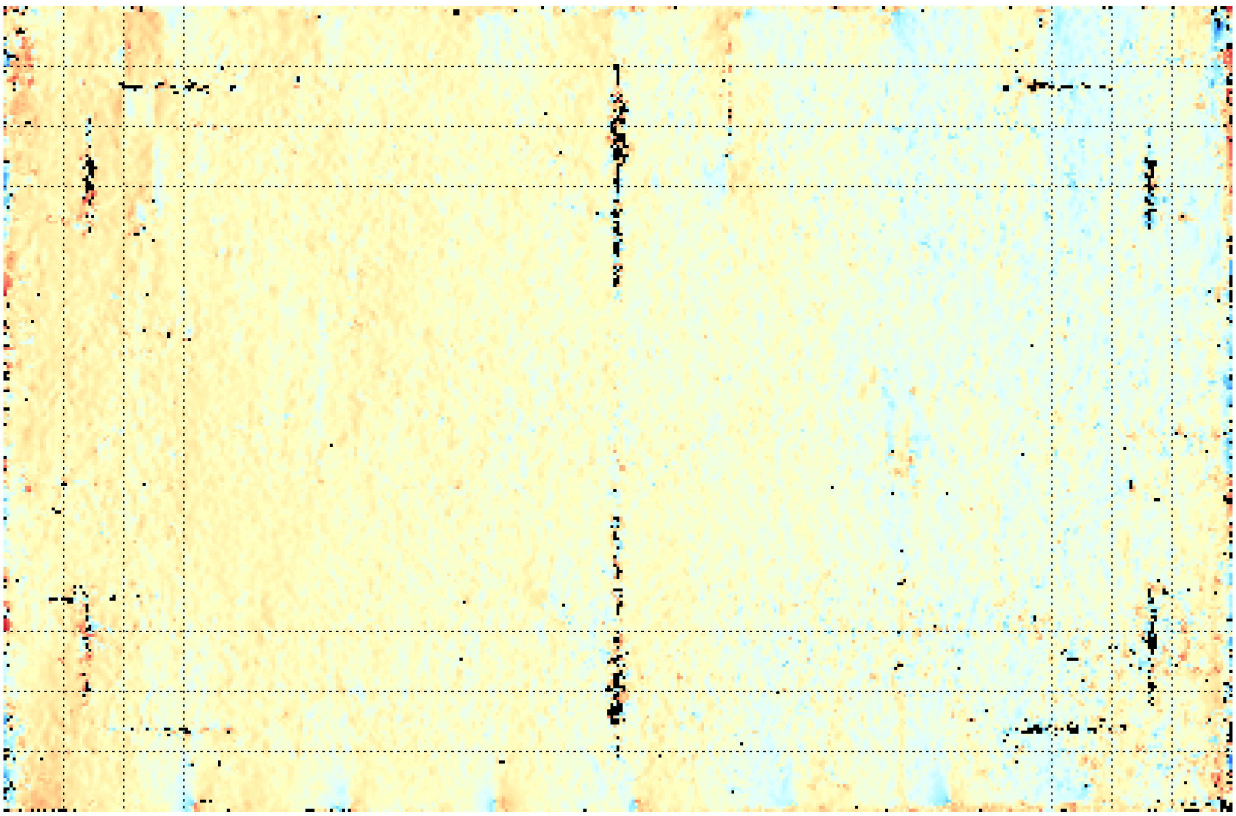


Figure 5: Horizontal (presumed weft) thread angle map for the entire painting. Horizontal and vertical dashed lines are separated by 5 cm and can be used to judge cusping depth and separation.

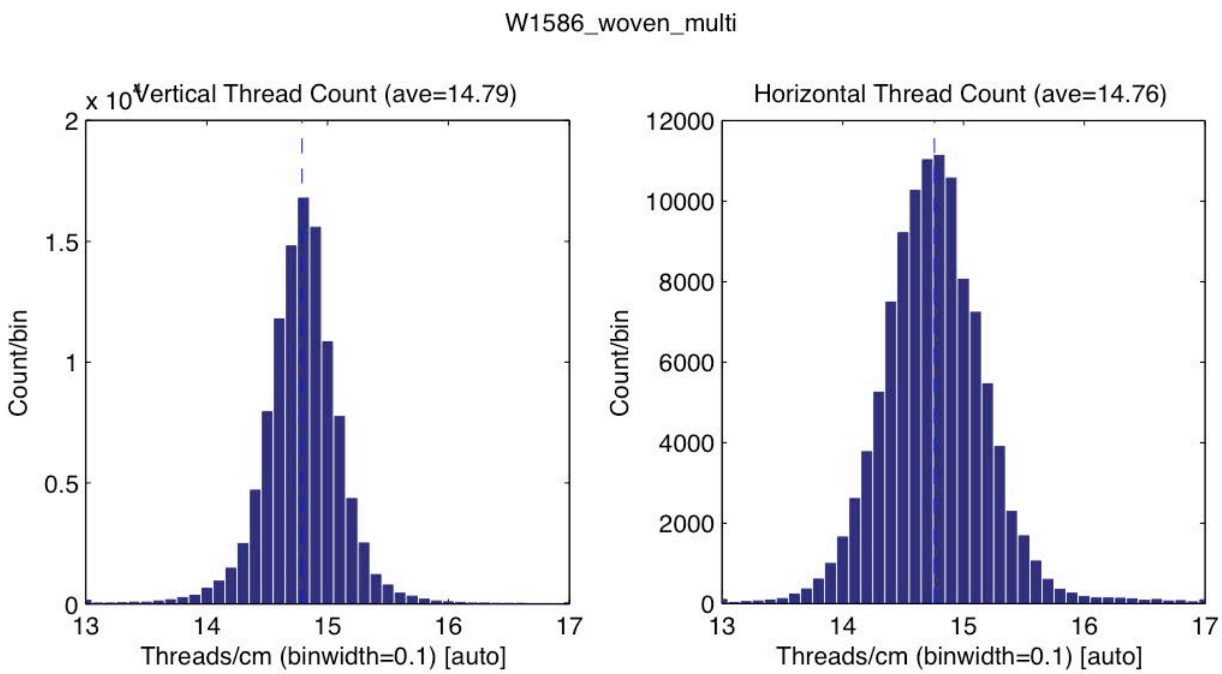


Figure 6: Thread count histograms for the entire painting.