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DETECTING WEFT SNAKES

C. Richard Johnson, Jr., Don H. Johnson, Ige Verslype, René Lugtigheid and Robert G. Erdmann

ABSTRACT Using recently developed image processing software, the presence of a wavy band of threads, occurring only in the weft direction of hand-loomed fabric, is vividly displayed in colour-coded maps of the local direction of the threads. Observation of a canvas-wide wavy group of threads labelled a 'weft snake' reliably establishes the warp–weft orientation of the painting's canvas, which is a key ingredient in identifying canvases from the same original bolt. A few examples of weft snake detection are provided in a range of European paintings across countries and centuries. The occurrence of 'weft snakes' appears more often than residual selvedges for old master paintings, and is equally reliable in designating the fabric's warp–weft orientation.

Introduction

Among the possible criteria described in Wetering (2009) for distinguishing the warp and weft directions in canvases 'whose selvedges were missing and in which there were no seams between two or more strips of canvas' is Number 7: 'groups of threads in one direction that show waves ... can always be identified as weft threads'.[1] The identification of groups of wavy threads as weft threads arises from recognition that the warp threads are typically under greater tension and less variable in direction than weft threads.

This paper considers a canvas-wide wavy group of threads, which we label a 'weft snake'. The weft snakes illustrated here are typically composed of 5–10 threads in canvases of 10–20 threads/cm, and are therefore only around 0.5 cm wide. Their angle variation is limited to plus and minus a few degrees. Therefore, they are difficult to observe in the X-rays used to count the threads in canvases of lined paintings. Our interest in weft snakes is motivated by their utility as a reliable weft direction indicator when observed.

We address three issues regarding weft snakes: detection, cause and prevalence. First, we show how recently developed automated thread counting schemes can produce a colour-coded map of the thread orientation within small evaluation squares across the painting surface, in the process providing a sensitive weft snake detector.[2] Second, we provide a description of the aberration in hand-loomed weaving that causes an overly tight weft thread thereby producing a weft snake. Third, we present the results of an ongoing examination of all paintings on canvas by Vermeer to support the observation that the occurrence of a weft snake can be more prevalent than retained selvedge.

Figure 1 presents an X-ray excerpt (approximately 4 × 10 cm) from *The Art of Painting* by Vermeer with a horizontal weft snake. This weft snake extends across the full 110 cm width of the painting. Selvedges remaining on the right and left sides of *The Art of Painting* confirm that its

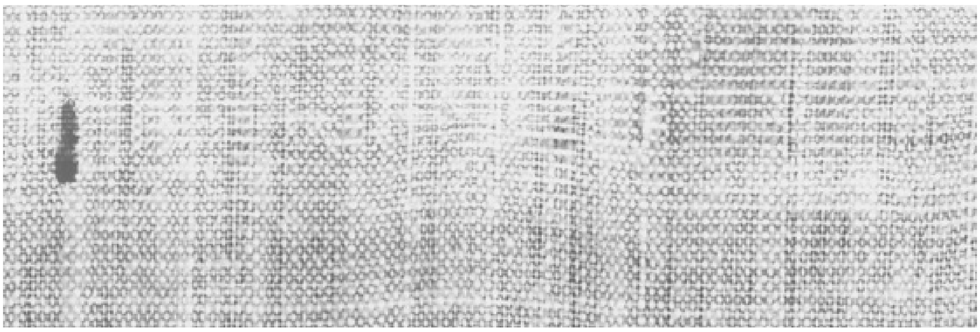

Figure 1 Weft snake visible in the X-ray of Johannes Vermeer, *The Art of Painting*, oil on canvas, 120 × 100 cm, c. 1666–68, Kunsthistorisches Museum, Vienna, inv. 9128.

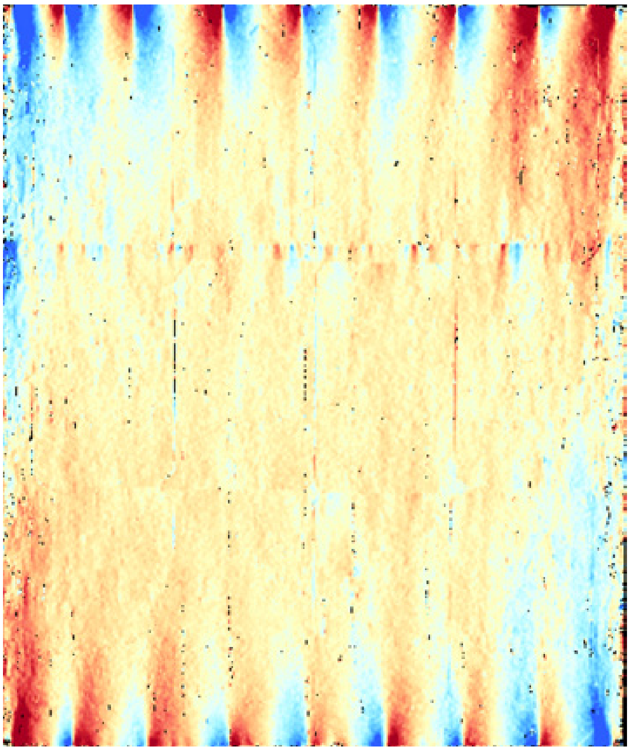

Figure 2 Weft angle map: Johannes Vermeer, *The Art of Painting*, oil on canvas, 120 × 100 cm, c. 1666–68, Kunstistorisches Museum, Vienna, inv. 9128; colour/angle range: deep red +10 degrees to deep blue –10 degrees.

vertical threads are warp threads, consistent with the horizontal orientation of its weft snake. Visually discovering a weft snake in an X-ray of a painting on canvas requires patient examination.

Weft angle maps as weft snake detectors

The automated thread count algorithm, introduced in Johnson et al. (2009) and applied and refined in subsequent studies by Johnson et al.[3] is based on a two-dimensional spectral analysis of the canvas weave pattern calculated from overlapping squares, usually 1 × 1 cm.[4] From these calculations, not only are the approximately horizontal and vertical thread counts produced, but also the angle of these threads within each evaluation square. Colour-coded maps for the thread counts and angles can be displayed for an entire painting from these results. In this paper, we concentrate on the angle maps, an example of which is shown in Figure 2.

Towards the middle of the diagram shown in Figure 2, the uniform colour suggests that thread angle does not vary much at all, which means that the horizontal threads run in a straight line in this region of the painting. Vivid colour variations at the top and bottom of the painting reveal that the horizontal thread angle varies significantly (about plus or minus 10 degrees). Such angle variations at a painting's edges are due to cusping, a distortion of the thread angle caused by stretching the canvas on a stretcher/strainer with nails or by lacing the canvas to a wooden frame. Once the artist or primer applies the sizing and/or ground while the canvas is stretched, these angular distortions are sealed. Consequently, finding departures of threads from a straight trajectory near the edge of a painting is not unusual and, when it occurs, both the nail spacing and the depth of cusping can be ascertained from angle maps.

About a third of the way down from the top of the weft angle map in Figure 2 is a less vivid but very noticeable angular variation that resembles weak cusping, but was not induced by mounting on a frame, or by contact with an inner edge of the stretcher. Such 'mid-painting' variations in the angle map could be caused by thread angle fluctuations that arise at a seam joining two canvas fragments to form the painting's support. If this were the case for this painting, one would expect a dramatic change in the vertical-thread weave density map at this juncture, which does not occur. Visual examination of the X-ray, such as in Figure 1, confirms that no seam is present. Since this feature of the angle map cannot be due to the artist's stretching of the canvas, we categorise it as a manufacturing fault, which is discussed in the following section.

As noted earlier, the canvas of the painting in Figure 2 still has its selvedges, which reveal that the horizontal threads are its weft threads. We call these wavy canvas-crossing artefacts weft snakes as only weft threads show this feature. In applying our automated thread counting software to over 600 paintings by over 40 artists ranging from Bouts to Matisse, we observed that:

- weft snakes do not occur in all paintings;
- when they do occur, they run across the full width/height of the painting's canvas;
- the spacing between weft snakes is erratic (our Vermeer example has only one in 120 cm of canvas while the Velázquez example shown in Figure 3 has two located near the top); and
- thread positions in a weft snake wiggle up and down (or side to side in the case of a vertical example) with a frequency of less than five full up-and-down wiggles per centimetre.

Figures 2–4 provide a gallery of weft angle maps displaying weft snakes in three paintings from three European countries by three artists from the seventeenth and nineteenth centuries: Vermeer, Velázquez and Monet. In displaying the angle of the horizontally oriented threads, Figure 2 exhibits cusping on both top and bottom. The weft snake detected by the horizontal collection of blue and red highlights about one-third down from the top edge in Figure 2 is the one excerpted in Figure 1. Figure 3 has cusping on the top and bottom and two horizontal weft snakes in its upper half. Figure 4 has cusping on its left and right sides and a vertical weft snake about one-fifth of the canvas width in from the right edge.

Causing a weft snake

In a woven fabric warp and weft are balanced. The warp consists of threads stretched on the loom. The weft is the

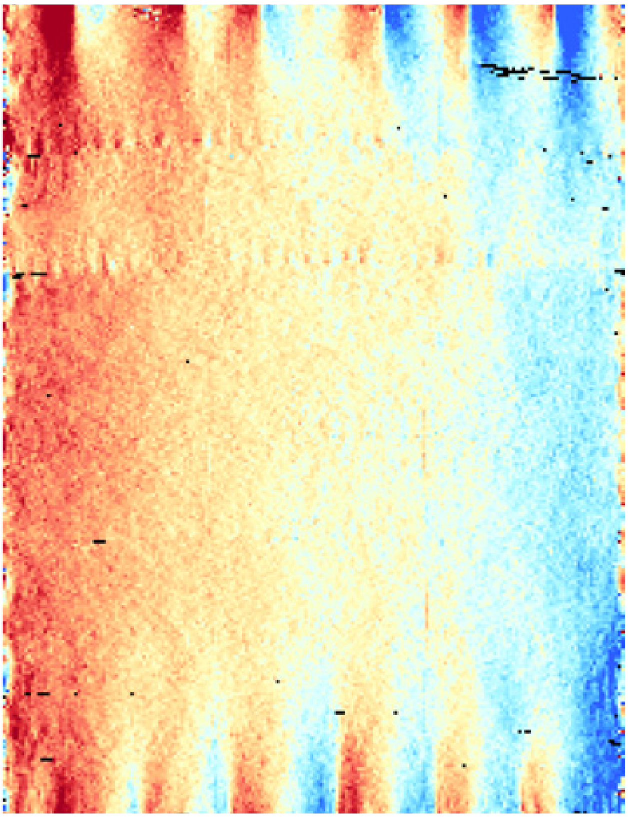

Figure 3 Weft angle map: Diego Rodríguez de Silva y Velázquez, *King Philip IV of Spain*, 1644, oil on canvas, 129.9 × 99.4 cm, Henry Clay Frick Bequest, Accession number: 1911.1.123; colour/angle range: deep red +10 degrees to deep blue −10 degrees.

thread with which the weaver forms the fabric. The warp is strung between the back beam and warp roller, on which the yarns to be woven are rolled, and the breast beam and cloth roller, around which the woven result is rolled. The weaver sits behind the breast beam. The warp threads are stretched between the two beams and pass successively through the heddles and the reed. The reed is fixed into the beater. With the beater the weft thread, after being passed through the warp threads, is pushed into the fabric. The distance between the bars of the reed determines the fineness of a fabric. The force with which the beater is pulled determines the density of the cloth. On a hand loom the weaver models the appearance of the fabric. Depending on the force with which the beater is pulled, hard or soft, a solid or loose web is created.

A weft thread shuttled across between the warp threads should be given some extra length to wind above and below the warp threads as is necessary upon beating. On a mechanical loom the length of a crossing weft thread is accurately determined, which produces an even fabric. On a hand loom, the regularity of the fabric is largely dependent on the touch of the weaver. A weft snake occurs when the laid-in weft thread has not been given enough length prior to beating. In such a case the weft thread is too tight. The warp, which is perpendicular to the weft, is drawn together by the tight weft thread. This happens despite the fixed spacing of the reed. This tight weft thread will cause compression waves in a few slackened weft threads

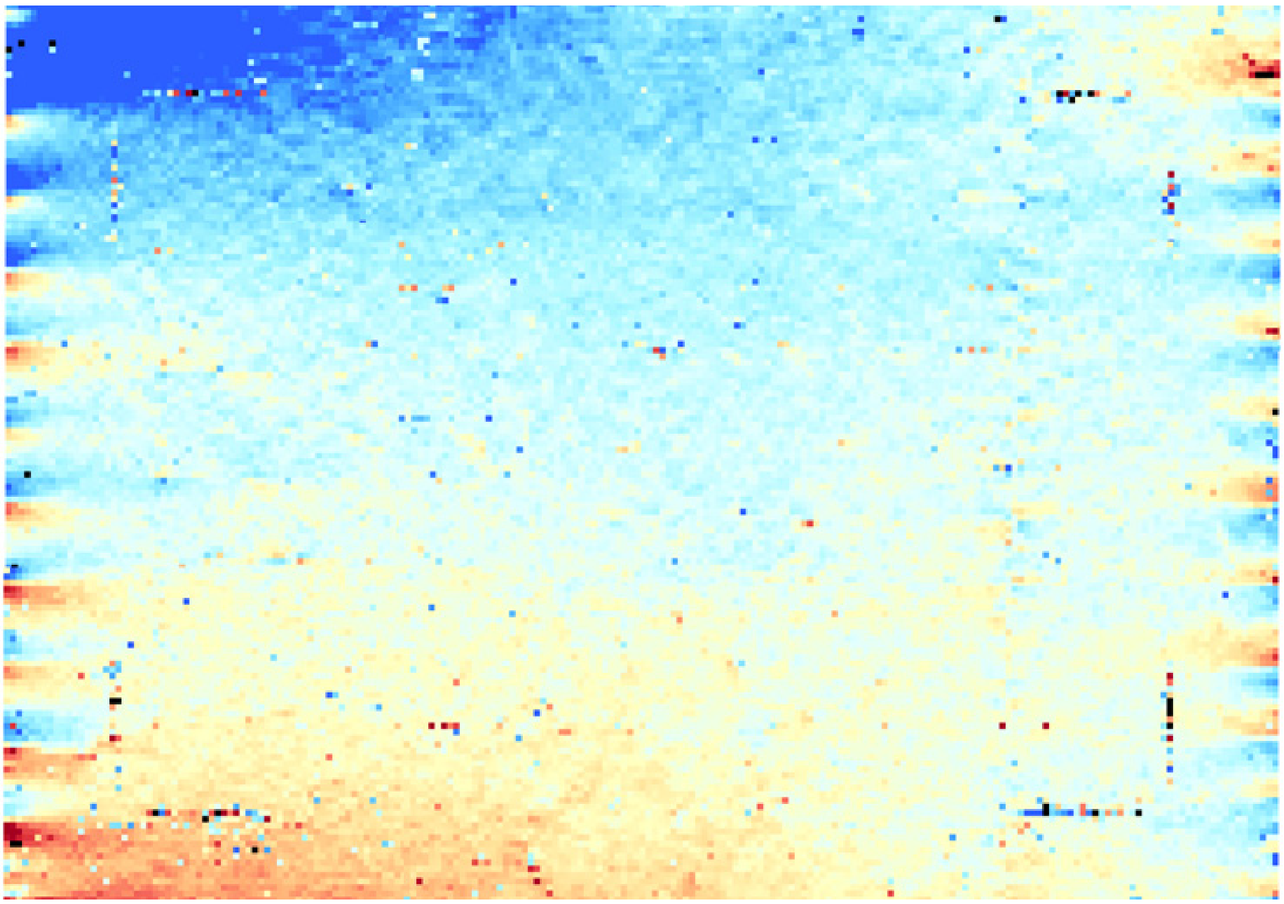

Figure 4 Weft angle map: Claude Monet, *The Beach at Sainte-Adresse*, 1867, oil on canvas, 75.8 × 102.5 cm, Mr. and Mrs. Lewis Larned Coburn Memorial Collection, Accession number 1933.439; colour/angle range: deep red +10 degrees to deep blue −10 degrees

Table 1 Johannes Vermeer weft snakes. L numbers from Liedtke (2008) were used as unique, compact identifiers of Vermeer paintings.

#	Title	Museum/gallery collection	H/V	Prominent snake location(s)
L01	*Diana and Her Companions*	Mauritshuis, The Hague	V	≈ 30 cm from right
L06	*Cavalier and Young Girl*	The Frick Collection, New York	V	≈ 15 cm from left & ≈ 13 cm from right
L09	*Young Woman Interrupted at Music*	The Frick Collection, New York	H	≈ 12 cm from top & ≈ 10 & 18 cm from bottom
L14	*Woman with a Lute*	The Metropolitan Museum of Art, New York	V	≈ 18 cm from right
L17	*Woman in Blue Reading a Letter*	Rijksmuseum Amsterdam	V	≈ 16 cm from right
L26	*The Art of Painting*	Kunsthistorisches Museum, Vienna	H	≈ 40 cm from top
L31	*A Lady Writing a Letter, with Her Maid*	National Gallery of Ireland, Dublin	H	≈ 30 cm from top
L33	*Young Woman Standing at a Virginal*	National Gallery, London	H	≈25 cm from top & ≈ 14 cm from bottom
L34	*Young Woman Seated at a Virginal*	National Gallery, London	H	Near middle

in the adjacent portion of the already-formed fabric. This flaw can be seen in the X-ray with some difficulty, but is easily discerned in the colour-coded weft angle maps, as illustrated in Figures 2, 3 and 4. The threads forming this flaw are always in the weft direction of the cloth.

A possible explanation for the existence of a weft snake is a break in the weaving process. During the rest period the tension on the warp threads can change. When the weaver continues weaving after such a rest period, some time may be needed to re-acquire the desired touch. Therefore, the initial impact can be somewhat irregular, possibly leading to a weft snake. This flaw would not be expected to appear in machine-made fabrics.

Vermeer weft snake hunting

Weft snakes were discovered during a project to draw weave maps of all paintings on canvas by Vermeer. We have examined X-rays of 24 of the 33 available paintings on canvas so far. Of these, nine (or just under 40%) have prominent weft snakes, as indicated in Table 1. Of the nine paintings listed in Table 1, six have no remaining tacking edges,[5] and therefore no retained selvedge to otherwise provide a confident warp–weft designation.

We use L numbers from Liedtke's *Vermeer: The Complete Paintings* as unique, compact identifiers of Vermeer paintings.[6] The Vermeer paintings examined that do not include a prominent weft snake indicator in the weft angle map are: L4, L7, L11, L12, L13, L19, L20, L21, L22, L23, L29, L30, L32, L35 and L36.

Conclusion

A slight increase in tension due to a laid-in weft thread of insufficient length causes a group of the most recently woven weft threads to go a bit slack and meander (see Figure 1). Such angle variation is readily visible in the typical weft angle map, as in Figures 2, 3 and 4. As an indicator of weft and warp direction in a canvas, the detection of a weft snake is as reliable as the presence of a selvedge. Among the paintings on canvas by Vermeer, weft snakes occur for a significant fraction of paintings for which no tacking edges or selvedges have been retained.

As weft snakes are expected to occur only with hand-driven looms, the earlier the painting the more likely it is to have a weft snake. Between 30 and 40% of the 33 paintings by Vermeer have the feature while only one or two of the nearly 400 paintings by van Gogh we have examined display the feature and, even then, it is very subtle. Even so, we have observed a considerable number of weft snakes in paintings by Monet and Matisse.

Access to scanned X-rays of high enough resolution of a sufficient number of paintings needed to support more definitive statements about the historical trends regarding the use of canvas containing weft snakes is years away. However, once a digital image database becomes available for which weft angle maps are computed, such comprehensive questions can be addressed.

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Notes

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Authors' addresses

- C. Richard Johnson, Jr., Cornell University, Ithaca, New York, USA (johnson@ece.cornell.edu)
- Don H. Johnson, Department of Electrical and Computer Engineering, Rice University, Houston, Texas, USA (dhj@rice.edu)
- Ige Verslype, Rijksmuseum, Amsterdam, The Netherlands (I.Verslype@rijksmuseum.nl)
- René Lugtigheid, Faculty of Humanities, Conservation and Restoration, University of Amsterdam, Amsterdam, The Netherlands (D.O.R.Lugtigheid@uva.nl)
- Robert G. Erdmann, Department of Materials Science and Engineering, University of Arizona, Tucson, Arizona, USA (erdmann@arizona.edu)