First International Workshop on

IMAGE PROCESSING FOR ARTIST IDENTIFICATION

BRUSHWORK IN THE PAINTINGS OF VINCENT VAN GOGH

Summary :: *This document describes the motivation and format for a workshop – to be held May 14, 2007, at the Van Gogh Musuem in Amsterdam – that is intended to accelerate the interaction of art historians and image processors interested in artist identification. The collection of digital images of artwork has been underway for over twenty years. Subsequently, in the last ten years image processors have initiated projects to process digitized images of paintings and drawings to assist art historians in artist identification. A key issue in the advance of this emerging technology, which is poised to expand rapidly over the next ten years, is bridging the gap between the two cultures of image processor system developers and art historian users. Five teams presently creating image processing schemes to assist the art historian in artist identification are preparing a daylong program for art historians and conservation specialists to introduce them to the potential of this technology. The Van Gogh Museum in Amsterdam and the Kröller-Müller Museum in Otterlo have provided these five teams access to a common database of digitized paintings by Vincent Van Gogh and his imitators. The Van Gogh Museum will host a workshop on May 14, 2007, to be attended by art historians and conservation specialists to whom the five teams will make presentations on brushstroke analysis in assistance of artist identification.*

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Assisting Artist Identification with Image Processing

The case for collecting digital images of artwork is summarized succinctly in [1]:

> "Although the usual records of paintings are large format transparencies (up to 10 in $\times$ 8 in), which have excellent resolution, they gradually deteriorate over time and have inaccurate color. ... Digital images promised permanence and color accuracy ensuring that images taken many years apart could be compared."

With rapid advances in digital imaging in the 1980s, museums worldwide have been assembling digital archives of their collections at a remarkable pace since then. As expounded at the turn of this century in [2], the next phase will be the processing of these digital documents:

> "Image processing will become more and more important in the museum. It could be of great use for measuring, counting, comparing, selecting, etc. Moreover it easily provides enhancement and restoration of documents. More and more it helps the scientist to objectively detect and recognize shapes and organizations which occur either at the micro-level (the painting dot ... or the brush-stroke ... for instance) up to the construction level of the painting. Very few results have yet been published on the subject, and the community of curators and art historians is often still skeptical on its real capability ... Intensive digitization of scientific archives and paintings provides a tremendous amount of information, more than 4 terabytes, available for art historians, scientists, and curators. ... Very little attention was paid to the systematic analysis of the collected data to help in understanding the artist's technique, the use of his tools, of the available material, his palette, his movement, his attempts. Also no systematic comparison was made on these bases between different artists, different schools, and countries. Most of the discoveries are yet to be made. ... For art historians and image processing specialists, it is a dawn of a new scientific approach."

Our special interest here is in artist identification, which is one of the major activities of connoisseurs and art historians [3, p. 15]:

> "Theories of connoisseurship - the practice of locating works of art in space and time and, more specifically, of attributing works of art to individual artists and assessing their quality on the basis of stylistic analysis and discernment of aesthetic value - have held a significant place in the historiography of art history."

[1] This document composed by R. Johnson (CU) and E. Hendriks (VGM). Revised January 17, 2007.

Not only does this statement in a recent book on the emergence of modern connoisseurship in Rembrandt studies provide a working definition of connoisseurship emphasizing artist identification, but it also points out the major role of this task, and theories about its practice, in the culture of art history scholarship. The survey [4] makes it clear that such connoisseurship is only one of several methods of Netherlandish painting analysis.

An early recipe for attribution scholarship by the late-nineteenth-century connoisseur Giovanni Morelli stressed that each painter has a discernible "signature", as summarized in [3, p. 91]:

> "By studying many paintings attributed to the same artist, beginning with those that could be securely authenticated and then proceeding to those originating from the same school of painting, the interested student should begin to create in his mind an image of the fundamental or characteristic forms ... of a master. Morelli believed that every artist developed particular forms for anatomical parts as hands (especially fingernails) and ears, as well as for landscape details."

Other contemporary experts, such as the primary, late-nineteenth-century Rembrandt scholar-connoisseur Wilhelm Bode, disdained such a "scientific" approach as [3, p. 97] "soulless and only concerned with superficialities of form."

The paradigm of Morelli's approach to painting attribution is similar to that of medical diagnosis, psychoanalysis, and criminal sleuthing, as elucidated in [5]. This methodology from Morelli can also be readily imagined as the basis of an artificial-intelligence-based expert system. However, even after putting aside doubts in the suitability of such a scientific approach to connoisseurship, the concern remains that the designation of signature features is fraught with subjectivity. Consider the exchange in the 1910s – exploiting the then recent introduction of macrophotography in painting evaluation – between two prominent Rembrandt scholar-connoisseurs, Abraham Bredius and Cornelis Hofstede de Groot, described in detail in chapter 6 of [3] and captured in conflicting comments on the "Portrait of Elisabeth Bas" cited in the brochure of the Rijksmuseum's recent (March 9 to May 24, 2006) display of a room full of "former" Rembrandt paintings:

> HdG: "I find these hands so unique, so masterfully executed."
>
> B: "They lack Rembrandt's broadness and his audacious use of paint."
>
> HdG: "Bol's hands are empty and characterless, weak beyond measure. Elisabeth Bas's hands are far stronger: typical Rembrandt hands."
>
> B: "These are the same fiddling hands as those of Elisabeth Bas: typical Bol hands."
>
> HdG: "The handkerchief: characteristic Rembrandtesque execution, well worked out yet loose."
>
> B: "The lace borders are prettily painted, quite different from Rembrandt's style."

> HdG: "Elisabeth Bas's handkerchief looks exceedingly like Mrs. Anslo's handkerchief [from a double portrait by Rembrandt]."
>
> B: "The loose, masterful brushwork of this handkerchief is quite unlike Elisabeth Bas's unconvincing handkerchief."
>
> B: "It must be clear to 99 percent of the viewers that the petty, second-rate execution of Elisabeth Bas's collar could never have been painted by Rembrandt."
>
> HdG: "What Bredius considers petty, I consider well worked-out."

The debate between Hofstede de Groot and Bredius about recognizing Rembrandt's hand in the visible painting surface also appears in de Groot's discussion of *Democritus and Heraclitus* cited in [3, p. 263]:

> "Where Bredius sees little pig eyes, I see a downturned gaze, whereby one naturally doesn't see much of the eye itself. Where he sees only skin, with no flesh behind it, I see a wonderfully plastic, modeled head. Where he reproaches the painter for a crusty impasto, I notice with regret the consequences of an English relining, whereby the original impasto was destroyed through ironing. The ear, which appears awful to Bredius, is for me an ear only cursorily indicated by Rembrandt in the shadows of the chiaroscuro, and the 'mouth, that goes far too much to the left' appears to me rather a shadow of the folds of skin arising through the action of laughing or of the moustache. In short, I see Rembrandt's hand in each brush stroke of this outstanding composition - certainly also still in the Elisabeth Bas portrait - and cannot accept the argument that Bredius introduces for Karel van der Pluym."

The key phrase here is in the summary statement: "I see [the artist's] hand in each brush stroke of this composition." Obviously Bredius disagreed with this claim.

The seemingly unavoidable subjectivity of observations and classifications plus doubts that artists could prove recognizably habitual across even modest variations in media, style, subject, and intent have fueled disagreement with and reinterpretations of Morelli's approach to painting analysis [6] [7]. The expansion since the 1960s of social, economic, and other forms of painting analysis not focusing on the object itself has tempered the prominence of connoisseurship in the academic art historian community [8]. However, even harsh critics of a Morellian form of connoisseurship as a dominant mode in painting analysis did not deny its limited utility [9]. Subsequently, during this period of decline in the academic standing of connoisseurship, some authors have argued for a re-emphais on the teaching and utilization of connoisseurship, e.g. [10], [11]. Furthermore, some prominent art historians remained unabashedly Morellian in their analyses, such as the study [12] of the oeuvre of Frans Hals, another Dutch brushwork virtuoso.

Despite the clash between art historians seeking a more objective basis for artist identification and those claiming its less quantifiable aspects are paramount, over the

last century the role of scientifically-based, technical, almost archaeological, examination in painting authentication steadily expanded. For a description of the breadth of techniques pursued in the technical examination of paintings, of which visible light and other image analysis form a small portion, see [13] [14]. However, current methods rely exclusively on human examination of the various images (macroscopic, microscopic, raking light, etc.) and do not presently draw on automated methods such as this workshop will showcase.

Even as the scientific basis expands, the resulting arguments for attribution are not always considered clearer or more persuasive, as noted in the commentary in [3, p. 325] on the impact of the Rembrandt Project begun in the late 1960s:

> "Advances in scientific investigation of paintings, through the use of infrared reflectography, autoradiography, dendrochronology, and more sophisticated pigment analysis, could now join with traditional visual analysis of style and technique as tools for connoisseurship. ... Despite the best efforts of the Rembrandt Project to escape the dominant subjectivity of earlier connoisseurs by working as a group, considering the range of scientific evidence, and insisting on articulating the reasons for their decisions, both their methodology and their findings have been subject to intense debate and criticism. ... Although they believed their 'attempt to define and purify Rembrandt's oeuvre' was justified by their 'effort to find rational, communicable arguments to support' their opinions, the sometimes prolix verbiage of the Rembrandt Research Project's argumentation has proven no more inherently convincing than that of earlier connoisseurs."

Admittedly, one difficulty in the use of "secondary" scientific evidence is that its interpretation is not always obvious, especially given a necessarily limited understanding of the artist's specific working practice on the particluar object under consideration. For example, infrared reflectography of two versions of the same composition with one (Nuremberg version) loose, "that is, relatively free in paint application", and the other (Hague version) smooth reveals that only one – the Nuremberg version – has changes beneath the surface paint [3, p. 326]:

> "Did this mean that only the Nuremberg version could be a Rembrandt, since it alone revealed the young artist's struggle translating his vision into paint? Or was it simply the first of two prime versions? Did the considerable difference in painting technique ... reflect Rembrandt's experimentation with two recognized categories of painting, the rough and the smooth, or did it provide evidence of two entirely different hands, in one case, that of a copyist?"

This is where an objective form of brushstroke analysis could prove different, given the assertion that it carries the artist's signature. Brushstroke analysis via digital image processing could conceivably serve as "primary" evidence. Though the presumption of the identifiability of the artist's unique brushwork signature has been repeatedly relied upon throughout the history of art history, the method of delineation of the

particulars of a brushstroke signature has never been standardized or quantified. Brushstroke signature recognition and its subsequent utilization remain subjective and idiosyncratic.

Brushstroke Analysis in Vincent Van Gogh Scholarship

The target artist of this workshop is Vincent Van Gogh. Attribution scholarship for Van Gogh is complicated by the large number of fakes and imitations that appeared in the decades following his death over 100 years ago [15].

As illustrations of recent Van Gogh attribution analysis employing significant technical examination, consider [16] and [17], which deal with questions of authorship in cases of similar paintings of the same subject. Anomalous brushwork is cited in both cases as part of the "evidence" of their not being by Van Gogh. In both cases this is explained away with further insight. From [16]:

> "... *Garden of the Asylum* [F659][2] was subjected in 1999 to extensive technical and stylistic examination. This included examination with the naked eye and the stereo-microscope, ultra-violet fluorescence, infra-red refelctography, X-radiography and paint sampling. ...
>
> The spontaneous and rhythmic, yet ordered application of brushstrokes is entirely characteristic of Van Gogh's touch. Their form, texture, consistency and functional orientation can easily be matched to examples in other of his paintings. ...
>
> In short, every aspect of the materials and technique used in *Garden of the Asylum* is consistent with what one finds in Van Gogh's *oeuvre* from the same period, namely, the rough cut of the canvas support from a pre-primed roll, its provisional stretching by the artist, the fact that the painting was stacked against other works when it was still fresh, the type and range of pigments used (inasmuch as comparative analyses are available), the discoloration of certain paint areas and the characteristics of the paint application. Technical examination thus provided absolutely no reason to doubt that the work was painted by Van Gogh. ...
>
> ... [F659], with its carefully worked out but stylised brushwork, is representative of only a small part of his *oeuvre*. Morevoer, the painting has the added disadvantage of having uneven passages, as Van Gogh's striving for consistency of linear description obviously caused him difficulty. ...
>
> This combination – an unusual type of work that also displayed a hesitant execution – was enough to cause vague doubts to mushroom into outright objections. The sceptics simply refused to give this somewhat atypical work a chance."

[2] In the remainder of this document paintings will be identified by either their F number from [18] or an S number from [19].

From [17]:

> "Although critics of the Tokyo still life [F457] have argued that the brushwork is atypical, comparison of the individual elements in fact reveals close parallels with the artist's other works. For example, the impasto texturing of the overblown sunflowers strongly resembles that employed in the Amsterdam version [F458]. The latter also displays a similar patterning in the background, which in places is structured by crosshatched or 'basket-weave' strokes. While the long parallel brushstrokes present in the foreground of the Tokyo still life may not occur in the other versions, comparable vertical strokes were used to depict the door in, for example, *Vincent's chair* [F498].
>
> Viewed in its entirety, however, the texture of the paint surface is somewhat idiosyncratic. Although the other sunflower versions exhibit a contrast between thinly and thickly applied areas, the Tokyo picture has a substantial paint layer throughout. Furthermore, the pronounced impasto in the foreground and vase seems particularly obtrusive and was undoubtedly a major source of the critics' mistrust.
>
> However, these authors have not taken into account the unusual choice of material for the picture support, namely jute. This sheds a different light on the heavily laden paint applied throughout ... The frayed ends to trailing brushstrokes criticised by Tarica are also the result of this coarse fabric: in places the corrugated surface has caused individual strokes to lose their definition, a clear example being the ragged edges to the final green contours around the stalks and leaves.
>
> Finally, while the particular paint application in the Tokyo still life closely resembles the brushstroke in Van Gogh's other paintings, it has little in common with that of Schuffenecker.
>
> ... [N]one of the aspects ... examined – the provenance, the picture support, the sequence employed in building up the image, the colour pallette, the brushwork – provide reason enough for eliminating the Tokyo *Sunflowers* from Van Gogh's oeuvre ...
>
> The above discussion makes clear that Van Gogh's artistic problems with the Tokyo still life arose through the unusual combination of a drastic approach to light-on-light painting and an equally extreme use of impasto brushwork. ...
>
> In short, Van Gogh truly wrestled with this picture, and ironically it is the results of this struggle that have given the critics reason to regard the work as a forgery. The lack of lucidity on colour and form gave rise to the opinion that the work was 'muddy'. This, along with the painting's long obscured provenance and the knowledge that it was once in Schuffenecker's possession – a man whose reputation was tainted by allegations of forgery – inspired the critics' mistrust, which was further fuelled by the lack of

> any mention in the letters and by the peculiar interpretative error in the stem enclosed by a leaf.

These excerpts indicate the modest role of brushstroke/texture analysis in the overall attribution assessment. They also provide an indication as to why each painting's brushwork has been considered atypical, as well as how the surface texture can be reassessed as exhibiting brushwork expected from Van Gogh in this circumstance. In one case the materials are cited as the cause for the anamolous brushwork and in the other the experimental style chosen by Van Gogh is the culprit. In both the hand of Van Gogh is said to be apparent. Recall, from [16]:

> "The spontaneous and rhythmic, yet ordered application of brushstrokes is entirely characteristic of Van Gogh's touch. Their form, texture, consistency and functional orientation can easily be matched to examples in other of his paintings."

And, from [17]:

> "Although critics of the Tokyo still life have argued that the brushwork is atypical, comparison of the individual elements in fact reveals close parallels with the artist's other works."

Can such observations be supported objectively? Can image processing schemes reveal the presence of the essence of Van Gogh in works of disparate materials, subjects, and style? Art historians seem to be willing to (de)attribute due to visible distinctions that seem uncommon to the excepted oeuvre. Can image processing schemes recognize these distinctions? How much side information (about, e.g., paint thickness and support texture) is needed to assist image processing schemes in explaining these distinctions in visible brushwork within one artist's body of work?

Similar questions of current interest to art historians – in the style of those concerning the brushstroke analysis in [16] and [17] – arise with attempts to support the following observations applicable to paintings within Van Gogh's oeuvre regarding the manifestation of brushstroke in a visible light image.

- Observation 1 (*Repetitions*): Ambiguously documented repetitions by Van Gogh with their technical differences and subsequent alterations by different collector-restorers admit forgery speculations.
  - ⊕ Examples: F659
  - ⊙ Compare: F632, F651, F652, F733, F734, F742
  - ⊗ Comments: See [16] regarding F659. We do not have access to its repetition-pair mate F660. However, for comparison, consider F651, F652, F733, F734 and F742, all of which (i) incorporate the slender tree trunk motif present in F659 and (ii) are currently dated in the same period (May to December 1889) [19][20]. F632 (from January 1890 [19]) is a landscape painted in the same time frame, and therefore presumably employing similar mature brushwork, but lacks the tree trunk motif and is after a painting by Millet.

- Observation 2 (*Atypical style with characteristic touches*): In portraits painted in a formal manner resulting from Van Gogh's academy attendance in Paris, impasto details can be identified as by the hand of Van Gogh while the principal surface texture is atypical for Van Gogh.

  ⊕ Examples: F215c, F215d

  ⊙ Compare: F208, F215, F215b, F370

  ⊗ Comments: All five paintings F208, F215, F215b, F215c, and F215d were originally dated by Faille as painted in 1886 [19] early in Van Gogh's Paris period. Since then, the attribution to Van Gogh of the two the portraits of women in F215c and F215d have been questioned. The datings have been questioned too, as being in the Antwerp or the Paris period. The forthcoming catalog [21] considers F215c and F215d to be painted by Van Gogh in March to early June 1886.

  F208 and F215 are two portraits currently attributed to Van Gogh from this same period [19] with visible brushwork and impasto highlights.

  F215b, which was formerly grouped with F215c and F215d, and therefore of uncertain attribution and dating, is now thought to be by Van Gogh, but the style of brushwork pushes the date of the portrait to January - February 1887 [21]. A notable detail is the stiff paint combed into fine ridges of impasto by the bristle hairs of a brush used to model the forehead. This technique parallels that used in F370 in the face of a contemporary portrait of the same woman.

- Observation 3 (*Substrate*): The substrate can effect the perceived texture of the surface painting, e.g. coarse jute versus linen or painting over a previous work poorly scrubbed away. The ground layer can further influence this effect. A thicker ground can disguise the substrate to a greater extent, and an absorbent ground will impede fluent brushwork to a greater extent than an oily one.

  ⊕ Examples: F256, F263a, F293, F546

  ⊙ Compare: S225, F486

  ⊗ Comments: The surface of the ready-made canvas used for F256 was "oiled out ... before use, overcoming the slight tooth of its fabric so that brush strokes could skid out into the wet layer of medium to create a luscious *alla prima* effect" [22].

  The self-portrait visible in F263a is comparatively thinly painted over a female portrait so that the "raised edges of loaded brushstrokes and high impasto [from the hidden female portrait] are clearly visible on the painting's surface. ... In the background the flatter areas of paint either side of the head show patches and lines where paint of the underlying image was scraped down with a tool." [23]

  In F293 "the artist explored the visual properties of thinly primed and very finely woven fabrics in a sophisticated way, drawing loaded brush strokes

swiftly across the grainy surfaces to create speckled highlights in the water for example. ... even blotting paint with his fingers to achieve the wooly texture of the clouds" [22].

F546 is painted on very coarse jute, as is the similarly styled S225. S225 is attributed to Gauguin. The attribution of F546 to Van Gogh has been questioned.

F486 is also painted on jute [20]: "The rough texture of the paint surface in [F486] is a result of the support Van Gogh has here employed: jute. ... despite the ground layer the open structure of the weave meant the paint was rather easily 'absorbed'. Painting on such a surface required a certain dexterity. Due to the inherent qualities of this somewhat wilful material, Van Gogh's free, individual brushwork here becomes almost invisible."

Actually, F486, F546, and S255 are painted on pieces of matching very coarse jute cut from the same roll of fabric and thinly prepared in the same manner with absorbent types of grounds. This provided a similar substrate on which to paint in each case, largely disqualifying the picture support as a cause of different brushwork textures. These works on jute by Van Gogh and Gaugin were painted when sharing a studio in Arles in the period October to December 1888, so that they display mutual influence in style and technique.

- Observation 4 (*Paint thickness*): Van Gogh's experiments with thin layers of paint and thick wet-on-wet application can lead to the use of modestly different artist application action and substantially different finished surface texture.

  ⊕ Examples: F255, F256

  ⊙ Compare: F219, F253, F253A

  ⊗ Comments: F219 has been dated March/April 1886 [20], F253 to various months in 1886 [19], F253a to the first half of 1887 [19], F255 as late 1885, to late 1886 [19], and F256 as late 1886 [19]. Therefore, this group contains works close in date, but with different manners of wet-on-wet paint application.

  In F255, which is painted over a previous composition, [23]: "The wet in wet nature of much of the paint application means that many of the sketchy brushstrokes intermingle. This is particularly evident in the background which seems roughly divided into three parts; the warmer, shadowed foreground to the left uses some parallel diagonal hatches. Immediately behind and to the right is a large lighter area of horizontal and sketchy zig zag strokes establishing the middle-ground. To distinguish the upper background, the direction of brushstrokes becomes uniformly vertical with a band of long dark green stripes running the length of the canvas, right to left. The edges of fluid brushstrokes tend to be undefined and subsequently difficult to measure. In addition the surface topography is complicated by the loaded underlying brushstrokes."

In F256 [23]: "Brushstrokes were layered wet-on-wet, building up to a considerable thickness in the shrimps. Surface texture was skilfully modelled with the brush, such as the choppy orange highlights in the shrimps formed by a succession of adjacent short strokes. Brushwork in the seaweed and background has a very loose, almost slapdash quality. Fairly broad brushes were used throughout, with the exception of the fine pencils used to detail the shrimps." [The use here of "pencil" matches 19th century usage, i.e. a fine pointed brush, as opposed to the more modern usage, i.e. a graphite writing tool.]

While F219, F253, and F253a are all executed wet-in-wet, their attribution to Van Gogh has been questioned. The attribution of F219 to Van Gogh was first questioned in the 1980s [20]: "The brushwork is of varying quality, with, at the upper left, numerous angular, diagonally placed and more or less disorderly strokes, and, at the upper right, a much more systematic structure of horizontal parallel lines. It was obviously painted wet-in-wet". In F253 [23]: "The paint is thick and opaque enough to mask the underlying image beneath. Some areas are made up of raised, textured paint from short, laden brushstrokes such as the items on the plate described in shades of yellow to orange and brown. The paint which describes the glass items are made with finer strokes of drier paint black shadow and white highlight which appear dragged over the layer beneath. In the rest of the still life paint is more fluid and heavily applied in long brushstrokes such as the shades of off-white to brown/grey strokes forming the plate and those in the background. ... Two compositions have been applied to the canvas, the first was not fully dry when the overlying image was painted on top as there is a large area of drying cracks in the upper, left background. The visible image appears to have been completed in one stage probably fairly quickly using thick paint to mask the layers beneath. No intermediate layer or scraping down is apparent." For 253a [23]: "Some of the earlier painted strokes, generally the darker colours and shadowing are executed with a wet-in-wet technique. As the numerous strokes of colour and especially highlight are laid in paint strokes become much thicker and appear rugged rather than fluid as they are dragged over the layers beneath. The result of this layering is a generally raised impasto surface in the still life and also in the highlighted foreground. ... The current image appears to have been laid over an underlying image when it was at least semi dry or scraped down. The still life and background were painted simultaneously as their borders mix wet in wet with one another. The still life may have been built up thickly to mask paint layers beneath." F253 and F253a were both attributed to Van Gogh in [19], but both will be de-attributed from Van Gogh in the forthcoming catalog [21].

- Observation 5 (*Contemporaries*): Paintings by proximate contemporaries admitting confusion in provenance, especially in the Paris period which lacks letters between Vincent and Theo, have proven challenging for confident attribution.

⊕ Examples: F233

⊙ Compare: S218, F229, F230

⊗ Comments: F233, which has been generally dated to late 1886, has long been considered not by Van Gogh [19]. F233 is similar to S218 on panel by Fabian. Though S218 is on panel and F233 is on canvas, F233 is prepared with an even layer of brown underpaint, imitating the effect of painting on panel. S218 and F233 exhibit similar brushwork, in the sky in particular. In the forthcoming catalog [21], F233 will be attributed to Fabian.

F229 and F230 are typical landscapes, matching the subject of F233, attributed to Van Gogh from the summer of 1886 [19], which is close to the period Faille designated for F233.

- Observation 6 (*Brushstroke experiments*): Van Gogh's experiments with pontillism, blocking with slabs, Japanese "copies", etc. through his time in Paris resulted in brushwork patterns that are visibly distinguishable from each other and his later, mature style(s).

  ⊕ Examples: F338, F342, F358, F371, F374

  ⊙ Compare: F418, F799

  ⊗ Comments: F338 has a thin paint layer and prominent parallel diagonal and vertical strokes in the background and is [23]: "a good example of the very thin painting technique combined with the Neo-impressionist touch that Van Gogh used in the period."

  F342 is [20] "one of Van Gogh's most consequent applications of neo-impressionist principles. The thinly applied pointillist brushwork and the contemporary colour contrasts ... are systematically thought through and executed."

  In F358 [23]: "Working within the areas delimited by underdrawn contours some features such as the background and some book covers are filled in with flat blocks of colour. The colour is often applied relatively thinly and evenly. Dry application results in spots and patches of light coloured ground being exposed at the surface where the paint does not flow into interstices of the canvas. Characteristic of the artist is that the areas are loosely filled in so patches of ground are frequently visible along contours. Elsewhere the paint is more thickly and fluidly applied resulting in numerous ridges at the sides of loaded brushstrokes and some patterned peaks of paint at the ends of brushstrokes."

  F371 copies a Japanese original [23]: "Throughout the artist has experimented with passages of thin wash and more characteristic thicker applications of paint. His painted interpretation of the print moves away from the one dimensional, flat areas of colour by using shadow and highlight in the main tree trunk and by apply some short, multidirectional, loaded brushstrokes and impasto peaks. Impasted paint is especially dominant in the yellowy middle-ground which dissects flatter areas of paint. In this way the

three layers of the image – fore, middle and back ground are distinguished by texture as well as by colour."

In F374 [22] "colour was applied using more solid, even 'slab-like' marks of the brush which strengthened effects of simultaneous contrast whilst taking stylisation to new extremes, providing oddly faceted forms in the cabbage for example." This painting is on twill canvas with a pronounced diagonal bias that is evident in thinner passages of paint application.

F799 is an unquestioned example of Van Gogh's mature style painted in mid-1890 [19].

Despite the prominent brushwork reminiscent of Van Gogh, F418 is no longer attributed to him [20].

- Observation 7 (*Non-sequential development*): The variety of technical and stylistic experimentation in Van Gogh's work, jumping back and forth in testing different aspects of style and technique, rather than following an obvious progressive development, makes it difficult to fix the date of some paintings on stylistic and technical grounds.

  ⊕ Examples: F177a, F572

  ⊙ Compare: F61r, F122, F160

  ⊗ Comments: F61r, F122, and F160 are all confidently dated in late 1884 or early 1885 [19].

  Brighter colors and bold brushwork in F177a have led to the picture being variously dated from late 1885 (in Neunen) to late 1886 (in Paris) [24].

  The attribution of F572 to Van Gogh has been doubted. The dating is also confused [20]: "The rendering of the long grass or reeds ... vaguely recalls certain of the late Paris works [such as F583]. The subject matter, on the other hand, is very Dutch, but of course this does not correspond to the bright palette. The picture is therefore difficult to place and cannot really be compared to the other works painted in the autumn of 1888."

Emerging Computer-Aided Image Processing Schemes Assisting Artist Identification

A presumption throughout the preceding discussions of these art historical issues, which is widely accepted in the community of connoiseurs and art historians, is that each artist employs a unique "rhythm" in execution that is visible in the brushstrokes and texture of a painting. In the past decade, image processing schemes have been proposed for processing greyscale digitizations of color transparencies of paintings and drawings with the intent of artist identification [25]-[29].

In [25] and [26], which were presented at the same conference, the authors from Vienna University of Technology, develop a stroke detection scheme as one level in a heirarchical approach to classification of the painters of nearly 600 portrait miniatures

of the Austrian royal family from the 18th and early 19th centuries. A training set of face segments selected by an art historian as containing characteristic brush strokes is used to parameterize either a model based stroke operator or a more generic multi-layer feedforward neural network. The artist-specific nature of this approach is viewed [26, p. 172] as enhancing its classification potential relative to more traditional technical analysis of paintings:

> "It is often difficult to attribute works of art to a certain artist. In the case of paintings, radiological methods like X-ray and infra-red diagnosis, digital radiography, computer-tomography, etc. and color analyses are employed to authenticate works of art. But all these methods do not relate certain characteristics of an art work to a specific artist - the artist's personal style. In order to study this personal style, we examine the "structural signature" based on brush strokes in particular in portrait miniatures. ... A heirarchically structured classification scheme is introduced which separates the classification into three different levels of information: color, shape of region, and structure of brush strokes."

The application base in work done by researchers at Penn State University [27] is Chinese ink paintings from the 15th century to the 20th century. As stated in the abstract and conclusion of [27], this work also has the intent of distinguishing the artist's individual "signature":

> "This paper addresses learning-based characterization of fine art painting styles. The research has the potential to provide a powerful tool to art historians for studying connections among artists or periods in the history of art. ... To profile the style of an artist, a mixture of stochastic models is estimated using training images. ... These models form an artist's distinct digital signature. ... Much work needs to be done on the applications of such techniques to assist art historians ..."

In [28], the authors from Dartmouth use wavelet statistics from segmented multiresolution images of the artworks to create an attribution vector. Clusters of the endpoints of these vectors in the attribution vector space designate the works of an individual author. This approach can be used on segments of artworks to address the distinction problem with many artists contributing separate portions of a single artwork. The applications in [28] were a set of 16th century drawings attributed at various times to Pieter Bruegel the Elder and a "many-hands" late 15th century altarpiece from the studio of Perugino. The authors make the claim that the automatic analysis of paintings through the use of digital image processing techniques is a promising field in its infancy [28, p. 17010]:

> "We have presented a computational tool for digitally authenticating or classifying works of art. ... We expect these techniques, in collaboration with existing physical authentication, to play an important role in the field of art forensics."

In [29] researchers from Maastricht University enhance parallel contours by processing the image with a circular filter, fill closed contours, skeletonize them, and fit the thinned brushstrokes to a high order polynomial. The resulting polynomial coefficients for each brushstroke are plotted as coordinate values creating a cloud of points, the localization of which in the polynomial coefficient space is unique to each artist. The results of analyzing 169 paintings by Van Gogh are considered a promising start [29, p. 31]:

> "Our analysis techniques are only the start of a promising development to explore the possibilities of automatic visual examination of Van Gogh's paintings. The qualifying results on analysis of colour and texture reveal a glimpse of the potential of digital image-analysis and machine-learning techniques. ... the use of advanced digital analysis techniques will change the way in which the authentication of visual art is currently performed."

The teams originating these four efforts provide four of the five image processing teams participating in the May 2007 workshop. The fifth image processing team is led by a pioneer in wavelet transform theory, which is a prominent tool for image texture analysis in a wide range of applications. With their participation in this workshop, these five teams are seeking feedback from the ultimate users of their schemes at a critical stage in their development.

Bridging the Gap with a Tutorial Workshop Around a Common Database

A recent survey [30] emphasizes the gap between the two cultures of art historians and image processors as a main challenge in the growth of a cross-disciplinary future:

> "Possibly due to a historical division between science and the humanities, interaction between the two worlds has never been natural or cherished. This is especially the case in the arena of signal and image processing techniques for artwork analysis and restoration. As a matter of fact, the application of signal and image processing to the analysis of artworks is still a very uncommon practice, among both conservators and information and communication technology specialists. Lately, however, there has been a greater focus on acquiring and processing artwork image data for storage, transmission, representation, and analysis. ... Efforts in this field have been supported by promising results, which have proven the potential impact of digital image processing on all related major issues, such as material analysis (and therefore dating and provenance determination), discovery and interpretation of ancient technologies, analysis of artists' environment and mutual relationships, better knowledge of conservation materials and processes, and art dissemination and fruition. ... In many cases, the main obstacle to the application of image processing technologies to the art field is the cultural clash between researchers with

> a technical background and researchers belonging to the humanistic area. ... In spite of the ... difficulties, there is a clear demand for new computational tools to help learn more about works of art. Hence, there is no doubt that the application of image processing to the investigation of visual art works will be one of the hottest signal processing research areas in the years to come."

Digital signal processing can contribute to the domain of art analysis by designing and developing tailor-made filters to bring out characteristics from (libraries of) digital reproductions of interest to art experts. As indicated by [25]-[29], such supplements to the art historian's toolbox are currently in the earliest stages of their development making it a most fruitful time for cross-disciplinary exchanges in enhancing these efforts. This workshop is an attempt to catalyze this interaction.

Such image processing is the latest manifestation of a long history of support for the arts from science and technology. Science and technology have played a substantial role in painting appreciation, attribution, and conservation since the early eighteenth century [13] [31], for which [16] and [17] serve as contemporary examples. Chemical analysis of paints can reveal the forger's use of a paint not available in the time period being faked. Infrared, ultra-violet, and x-rays can be used to reveal layers beneath the paint surface to view changes made by the artist in perfecting the composition and provide insight into an artist's techniques and intentions. Wooden panels can be examined via dendrochronology (tree-ring dating) and paint layers can be subjected to radiocarbon dating to assist the art historian in confirming the age of a painting. Each of these technologies has been used to support the analysis of paintings by connoisseurs and art historians, who traditionally rely more on available historical documentation of the painting's provenance, their understanding of the artist's body of work, and their reaction to the individual painting. Visible image processing is poised to join these acknowledged support technologies. At issue is

(i) how to persuade and train the art historian community to appreciate and utilize such tools and

(ii) how to convince the image processor community to develop techniques and systems that fit comfortably into the art historians' set of working tools.

To create a forum for confronting these issues, the five teams of image processors are preparing a one-day set of tutorial presentations intended for delivery to art historians and conservation specialists in May 2007. The five academic teams (from Vienna University of Technology, Penn State University, Dartmouth – Georgia Tech, Maastricht University, and Princeton University) were given a common database of 101 digitized greyscale images of paintings from the collections of the Van Gogh Museum and the Kröller-Müller Museum in the fall of 2006. In addition to tutorial talks introducing the pertinent concepts of image processing, each team will prepare a study on their particular approach to analyzing (portions of) the common database. A (closing) panel of art historians is planned to provide feedback to the image processors.

The Selected Paintings

To accomodate the thirty-nine paintings cited in the earlier observations related to Van Gogh's brushwork and to be certain to provide representative paintings from all segments of Van Gogh's decade as a painter, the following 101 paintings from the Van Gogh and Kröller-Müller Museums were selected for the dataset for the workshop. The list begins with F-numbered works and then lists S-numbered works. All titles for paintings with F numbers are drawn from [18]. The paintings with F numbers were at some point attributed to Van Gogh, though some are not currently. The twenty-three paintings marked with a (T) form the "training" set of paintings, are unquestionably by Van Gogh, and span his career and its styles. Eight paintings formerly attributed to Van Gogh are marked with an (F) [19][20][21]. Six paintings curently attributed to Van Gogh, for which this attribution has been questioned in the past, are marked with a (Q) [19][21]. Ultimately, the (F) and (Q) designations rely on the current opinion of the Van Gogh and Kröller-Müller Museums. The paintings with S numbers are attributed to painters other than Van Gogh [19]. The (sight or painting) dimensions (height x width) indicated for the F-numbered paintings were gathered through the following procedure: (1) from [20] or [23], when available, (2) if not, then from [32], when available, (3) if not, from [18]. The dimensions of the S-numbered paintings are from [19].

1. F25 (T) "Coming Out of Church in Neunen" [41.3 x 32.1 cm]
2. F61r "Still Life with Box and Other Objects" [31.5 x 41.7 cm]
3. F61v (T) "Self Portrait" [41.1-41.6 x 31.4 cm]
4. F76 (T) "Still Life: Satin Flowers and a Bowl with Leaves and Flowers" [42.7 x 31.7 cm]
5. F77v "Self Portrait" [43 x 32.5 cm]
6. F82 (T) "The Potato Eaters" [82.0 x 114.0 cm]
7. F101 "Still Life: Basket with Apples" [33.5 x 44.0 cm]
8. F122 "Avenue of Poplars: Autumn" [99.0 x 66.0 cm]
9. F130 "Head of a Peasant Woman with White Cap: Front View" [42.7 x 33.5 cm]
10. F160 (T) "Peasant Woman in a Red Bonnet" [43.0 x 30.0 cm]
11. F174 "The Midwife: Head with White Bonnet" [39.7-40.0 x 50.2-50.5 cm]
12. F177a "Stuffed Kalong" [41.5 x 79.0 cm]
13. F206 (T) "Head of a Woman: Nearly Full face" [35.0 x 24.4 cm]

14. F208 (T) “Self Portrait with Pipe: Three Quarters to the Right” [27.0-27.2 x 19.0 cm]
15. F208a “Self Portrait with Felt Hat” [41.4-5 x 32.4 cm]
16. F212 “Skull with a Burning Cigarette” [32.2 x 24.5-24.6 cm]
17. F215 (T) “Nude Study: Little Girl Seated” [27.1 x 23.4-23.5 cm]
18. F215b (Q) “Portrait of a Woman: Facing Right” [26.4-26.5 x 21.0-21.1 cm]
19. F215c (Q) “Portrait of a Woman with Hat” [27.0 x 18.9 cm]
20. F215d (Q) “Portrait of a Woman: Seated” [32.3 x 22 cm]
21. F216a “Plaster Statuette: Female Torso, Seen from the Back” [46.1-46.2 x 37.9-38 cm]
22. F216i “Plaster Statuette: Female Torso with One Leg, Seen from the Side” [32.9 x 23.9-24 cm]
23. F219 (F) “Still Life: Basket with Apples, Meat and a Breadroll” [45.9 x 55.0 cm]
24. F229 “Montmartre: Quarry, General View” [31.9-32.0 X 40.9 cm]
25. F230 “Montmartre: Quarry, The Mills” [56.0-56.3 X 62.2 cm]
26. F233 (F) “Montmartre: Quarry” [22.3-22.4 x 32.9 cm]
27. F234 (T) “Still Life: One-Eared Vase with Asters and Phlox” [61.1 X 46.1 cm]
28. F248a “Still Life: Vase with Gladioli” [46.5 x 38.3-38.4 cm]
29. F253 (F) “Still Life: A Bottle, Two Glasses and a Plate of Bread” [38.1-38.2 x 46.1 cm]
30. F253a (F) “Still Life: Plate with Rolls” [31.7-31.9 x 40.4 cm]
31. F254 “Still Life: Apples” [45.5-45.7 x 60.2-60.4 cm]
32. F255 “A Pair of Shoes” [37.8-38.1 x 45.2-45.3 cm]
33. F256 (T) “Mussels and Shrimp” [26.5 x 34.5-34.8 cm]
34. F260 (T) “Houses in Antwerp” [43.7 x 33.7 cm]
35. F261 (T) “View of Paris” [53.9 x 72.8 cm]
36. F263a “Self Portrait with Pipe and Glass” [61.1 x 50.1 -50.2 cm]

37. F266a (T) “Factories Seen from a Hillside in Moonlight” [21.2-21.5 X 46.2-46.4 cm]
38. F267 “Self Portrait: Three Quarters to the Left” [19.1 x 14.1 cm]
39. F278 (F) “Still Life: Vase with Daisies and Dahlias” [99.0 x 79.0 cm]
40. F292 (T) “Boulevard de Clichy” [46 x 55.3-55.5 cm]
41. F293 (T) “The Banks of the Seine” [32.0 x 46.0 cm]
42. F294 “Self Portrait with Straw Hat: Three Quarters to the Left” [19.1 x 14.1 cm]
43. F296 “Self Portrait with Gray Felt Hat: Full Face” [19.1 x 14.1 cm]
44. F297 “The Skull” [42.4-41.6 x 30-30.4 cm]
45. F304 “Pont de la Grande Jatte” [32 x 40 cm]
46. F309a (T) “Undergrowth” [46.1-46.2 x 55.2 cm]
47. F314 “Voyer-D’Argenson Park at Asnières” [75.0 x 112.5-112.7 cm]
48. F316 (T) “View from Montmarte” [81 x 100 cm]
49. F335 “Still Life: Three Books” [oval: 31.1-31.2 x 48.3-48.5 cm]
50. F338 “Still Life: Lemons on a Plate” [21.0-21.4 x 27.1-27.4 cm]
51. F341 “View from Vincent’s Room in the Rue Lepic” [45.9 x 38.1-38.2 cm]
52. F342 “Interior of a Restaurant” [45.5 x 56 cm]
53. F344 (T) “Self Portrait in a Gray Felt Hat: Three Quarters to the Left” [44.5 x 37.2 cm]
54. F356 “Self Portrait: Three Quarters to the Right” [41.1-41.2 x 33.1-33.2 cm]
55. F358 “Still Life: Romans Parisiens” [53.7 x 72.5-72.7 cm]
56. F370 “Woman Sitting in the Café du Tambourin” [55.5 x 47.0 (top)- 47.3 (bottom) cm]
57. F371 (T) “Japonaiserie: The Flowering Plum Tree” [55.6 x 46.8 cm]
58. F372 “Japonaiserie: The Bridge in the Rain” [73.3 x 53.8 cm]
59. F373 “Japonaiserie: Oiran” [100.7 x 60.7 cm]
60. F374 “Still Life: Red Cabbages and Onions” [50.0 (right)-50.2 (left) x 64.3 cm]
61. F377 “Still Life: Sunflower” [21,1-21.2 x 26.9-27.0 cm]

62. F400 “The Langlois Bridge with Road Alongside Canal” [59.5 x 74.0 cm]
63. F409 “View of Arles with Irises in the Foreground” [54.0 x 65.0 cm]
64. F411 “Wheatfield with the Alpine Foothills in the Background” [54.0 x 65.0 cm]
65. F412 “Harvest at La Crau, with Montmajour in the Background” [73.0 x 92.0 cm]
66. F418 (F) “The Sea at Saintes-Maries” [43 x 56 cm]
67. F423 (T) “A Bugler of the Zouave Regiment” [65.0 x 54.0 cm]
68. F464 “Vincent’s House on the Place Lamartine, Arles” [72.0 x 91.5 cm]
69. F469 “Self Portrait with Straw Hat” [40.9 x 32.7-32.9 cm]
70. F482 “Vincent’s Bedroom in Arles” [72.0 x 90.0 cm]
71. F486 “Les Alyscamps” [72.8 x 91.9 cm]
72. F499 “Gaugin’s Armchair, Candle and Books [His Empty Chair]” [90.5 x 72.5 cm]
73. F511 “Orchard in Blossom” [72.5 x 92.0 cm]
74. F522 (T) “Self Portrait in Front of The Easel” [65.5 x 50.5 cm] [65.0 (left) - 65.1 cm (right) x 50.0 cm]
75. F546 (Q) “Portrait of Paul Gauguin” [37.5 x 33 cm]
76. F555 “The Pink Orchard” [64.5 x 80.5 cm]
77. F572 (Q) “Willows at Sunset” [31.6 x 34.3 cm]
78. F607 “A Pair of Wooden Shoes” [32.5 x 40.5 cm]
79. F618 “The Wheatfield Behind Saint Paul’s Hospital at the Fall of the Day with a Reaper” [73.0 x 92.0 cm]
80. F632 (T) “The Plow and the Harrow” [72.0 x 92.0 cm]
81. F634 “Sheep Shearers” [43.5 x 29.5 cm]
82. F651 “The Walk: Falling Leaves” [73.5 x 60.5 cm]
83. F652 “Fir Woods at the Fall of Day” [91.5 x 72 cm]
84. F659 (Q) “The Garden of Saint Paul’s Hospital in Autumn” [71.5 x 90.5 cm]
85. F675 “Winter Landscape: Reminisence of the North” [29.0 x 36.5 cm]

86. F724 (F) "On the Border of the Alpilles" [59.2 x 73 cm]
87. F733 "The Garden of Saint Paul's Hospital with Figure" [61.4 x 50.4 cm]
88. F734 "The Garden of Saint Paul's Hospital" [91.5 x 72 cm]
89. F742 "A Clump of Trees in the Garden of Saint Paul's Hospital" [46 x 51 cm]
90. F746 "Undergrowth" [73.0 x 92.5 cm]
91. F764a "Still life: Vase with Rose-Mallows" [42.0 x 29.0 cm]
92. F765 "Corner in the Garden of Daubigny" [50.7 x 50.7 cm]
93. F779 (T) "Crows in the Wheatfields" [50.5 x 103.0 cm]
94. F799 "View at Auvers" [50.0 x 52.0 cm]
95. F816 "Trees, Roots and Branches" [50.0 x 100.0 cm]
96. S205 Emile Bernard, "Bernard's Grandmother" [53 x 64 cm]
97. S206 Emile Bernard, "Self-portrait with Portrait of Gauguin" [46.5 x 55.5 cm]
98. S218 (F) Fabian, "View from Montmartre" [12 x 22 cm]
99. S225 Paul Gauguin, "Portrait of Van Gogh Painting the Sunflowers" [73 x 91 cm]
100. S251 Adolphe Monticelli, "Vase with Flowers" [51 x 39 cm]
101. S274 Henri Toulouse-Lautrec, "Young Woman at a Table; Poudre de Riz" [56 x 46 cm]

Paintings F219, F278, F342, F418, F486, F572, F652, F724, F733, F734, and F742 are from the collection of the Kröller-Müller Museum. All others are from the collection of the Van Gogh Museum.

The digitizations of these paintings were done by the Maastricht team. They describe their color digitization process as follows:

> "The scans were taken of 4x5 inch ektachromes at 2000 dots per inch (dpi) using a Microtek ScanMaker 9800XL with TMA adaptor TMA 1600. The ektachromes were scanned 'as is' with all possible options (such as stretching the dynamic diapasons, etc) OFF. The bitrate used was 48 bits (16 per channel). The images were stored as TIFF files. Most of them have Kodak calibration lines which are split by colors and stored separately as TIFF files."

A single 16-bit-greyscale image (normalized to 196.3 pixels per inch of painting) was extracted for each painting to form the dataset that was distributed in fall 2006 for examination by the five teams with their image processing schemes.

Within this dataset there are numerous interesting subgroups in addition to the ones attached to the observations cited earlier regarding issues of disputed attribution and dating related to Van Gogh's brushwork. Groups of paintings that are not of uncertain attribution offer interesting test challenges to automated image processing schemes. For example, consider the four flower still-life paintings F234, F248a, and F278 and S251, two (F234 and 248a) of which are currently attributed to Van Gogh, one (F278) is formerly attributed to Van Gogh, and the fourth (S251) is by Monticelli. F234 and S251 are paired as plates 127 and 128 in [33], which includes the comment [34, p. 132]:

> "In Monticelli [Van Gogh] not only found many of the colour contrasts he was looking for, but the lush impasto of this painter from the south of France also appealed to him to develop his own heavy brushwork even further."

What conclusions regarding similarity and authorship can be drawn from automated brushstroke analysis of these four paintings that all seem quite similar to the untutored eye? The image processing teams intend to address such questions in their tutorial presentations at the workshop.

Workshop Program

The First International Workshop on Image Processing for Artist Identification focusing on automated brushstroke analysis of the paintings of Vincent Van Gogh is scheduled for May 14, 2007, at the Van Gogh Museum in Amsterdam. (For a listing of the workshop program schedule, registration forms, and other information, please visit *www.digitalpaintinganalysis.org/workshop/*.) The one-day program will begin with tutorial presentations of background for art historians in the image processing concepts used in the schemes – to be presented later in the day – created by each team for its analysis of the 101 painting dataset. The description of image processing concepts and procedures without resort to the rich language of mathematics, models, and algorithms foreign to art historians is an acknowledged challenge. A description of issues of art historical significance, such as the seven observations made earlier in this document, that depend on visible light image analysis will be presented before the five teams each present the results of their investigations.

The workshop program will also include a segment devoted to discussion on what comes next in this interaction of art historians and image processors. Consequently, the objective of accelerating the interaction of image processors and art historians interested in artist identification will be realized.

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