TECHNICAL NOTE

Multifractal Fingerprints in the Visual Arts

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The notion that nature can be described by fractal geometry was first suggested by Benoit Mandelbrot [1]. A fractal is a recursive, self-similar structure whose constituent parts in some way resemble the whole. Mathematically, these fractals are defined as

\[ N(d) \propto d^{-D_F} \]  

(1)

Here, \( N(d) \) is a measure of the number of “objects” that comprise the set at a viewing scale \( d \), and \( D_F \) is the fractal dimension, which can be interpreted as a measure of the irregularity of the structure. Simple, smooth shapes such as dots, circles or spheres have fractal dimensions that coincide with their Euclidean dimension. Conversely, a fractal is defined by a non-integer dimension that acts as a measure of the object’s roughness. For example, a line has dimension 1, but if it becomes very jagged at many scale levels, its dimension rises fractionally above this value—it has become a fractal. If the line becomes so jagged and rough that it effectively fills an area, then it has a fractal dimension approaching 2.

A recent surge of interest in fractal geometric “fingerprinting” of natural phenomena has included the study of artistic style. The style in question is gestural expressionism, a mid-20th-century technique in which the artist’s hand movements are guided by a philosophy of psychic automatism and the resulting images are seemingly disordered and chaotic. Researchers have proposed that a characteristic fractal dimension may be associated with the work of Jackson Pollock, identifying the physical distribution of pigment patterns as the associated fractal [2–5]. If a distinctive fractal dimension could be uncovered for every artist, this could pave the way for a novel form of artwork authentication. But is this technique sufficient to distinguish artists within the same gestural expressionist group? We chose to test the method by comparing the work of Jackson Pollock and the Quebec Automatistes, including artists such as Marcel Barbeau and Jean-Paul Riopelle.

A comparison was made between two groups of eight paintings each by Pollock and Les Automatistes. The images were digitized as 24-bit color files of sizes ranging between 1,000–2,500 pixels, and pigment patterns were filtered out according to a specified target color in RGB space (see Figs. 1 and 2). A variance in the values of the R, G and B channels (0–255 for 24-bit color) up to a specified distance from the

Fig. 1. Analysis of Jackson Pollock’s Reflections of the Big Dipper, oil on canvas, 1947. Image progression shows, from left, fragment of original painting; blob structure (black pigment); luminance edge structure (white regions).
target was allowed to account for any small fluctuations in the pigment shade. We calculated the fractal dimensions of the resulting patterns by the standard box-counting method, covering roughly three orders of magnitude of scale (1,000 pixels to 4 pixels per side), roughly several meters to a few millimeters in terms of the actual canvas dimensions. As the patterns are a result of random mono-chromatic pigment deposits, we hereafter refer to them as “blobs,” an etymology based on the “elongated blobs” identified by Julesz as distinguishable perceptual objects [6].

A one-way analysis of variance comparing the eight Pollock (mean $D_F = 1.79$) with the eight Automatistes ($D_F = 1.73$) paintings indicated that the $D_F$ indices were not significantly different, $F(1,14) = 1.18, p < 0.30$. This suggests that the fractal dimension of drip paintings is not unique to any one artist and cannot be used for any such type of authentication scheme. It should be noted that a more recent study [7] has found that a fractal box-counting analysis can differentiate between five Pollock and five non-Pollock images. These results can be considered to be consistent with those reported in this paper, since the non-Pollock images could be painted in such a way as to be “non-gestural.” Future analysis can shed more light on this finding.

Since a single fractal dimension rarely represents the true structure of a natural object, the **multifractal spectrum** of an image may provide a more rigorous way to classify the style or construction paradigm of paintings associated with a particular group such as gestural expressionists. A multifractal is a set whose form is a weave of overlapping self-similar configurations. These geometric formulations have been shown to describe the physical organization of a myriad of natural phenomena, ranging from tree-root growth to large-scale galaxy clustering [8,9]. Unlike simple fractals, multifractals are characterized by an infinite set of dimensions $\{D_q\} = \{D_0, D_1, D_2, \ldots\}$, calculated in a manner similar to $D_F$, which determines the scaling structure as a function of the local pattern density. The subscript $q$ is generally an integer, where $q = 0$ corresponds to the classic fractal dimension ($D_F = D_0$). The regions of densest clustering, represented by extremely large values of $q$ (or $q \to \infty$), scale according to the dimension $D_q \ll D_0$.

These two statistics, and all those in between, give a much deeper insight into the physical organization of the object in question and in fact can be used as a method of identifying the associated for-

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Fig. 2. Analysis of Marcel Barbeau (Les Automatistes), black pigment pattern from *Tumulte*, oil on canvas, 1973. Blob (left) and edge structure (right).

Fig. 3. Analysis of Tsion Avital, $K_M(C_3/C)$, oil on canvas, 200 × 150 cm, 1963. (© Tsion Avital) Example of systematic art. Raw image (left); edge structure (right).
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ture (\(DF\)) of paint blobs can be used to differentiate between "classes" of painting but not conclusively between different artists within the same class. The multifractal spectrum is interpreted here as the signature of an artistic style [12].

How then can one distinguish between artists within particular stylistic groups? It has been noted that humans have a preference for fractal dimensions of about 1.8 [13], which suggests that the gestural expressionists adapted their works to this special dimension. However, according to Berlyne [14], test subjects were found to have a visual propensity for images that are less complex, or contain more symmetric and homogeneously distributed information. This fact was more recently confirmed independently by Taylor [15], who reports that human visual preference is tuned to \(D_f \sim 1.3\). The images deemed "pleasing" in Berlyne [16] consist of regularly overlapping Euclidean shapes, which would suggest a fractal dimension closer to (but greater than) 1. This poses the very interesting question of why these artists gear their paintings to such high values if they are not deemed "perceptually favorable."

Moreover, if there is no appreciable difference between the base fractal sta-
tistics for the pigment distributions, as in the case of the images in Figs 1 and 2, what is it about the paintings that can impart differing visual sensations? In their seminal work, Hubel and Weisel [17] have established the principle that the brain is naturally disposed to analyze visual structures in terms of edges. A study of the edges on these canvases should thus reveal new information about the perceptual nature of the artworks.

The standard RGB primary color decomposition can be seen as a reflection of the eye's sensitivity to specific wave-lengths of light via the L, M and S cone cells. Based on the notion of edge detectors in the brain, it makes sense to approach the problem in a different color space representation called YIQ. This approach offers an alternative method for decomposition of chromaticity information in terms of luminance (Y), hue (I) and saturation (Q) instead of red, green and blue primaries (see, for example, Foley [18] for further details on color spaces).

The paintings by Jackson Pollock, Les Automatistes and Tsion Avital were compared in terms of luminosity gradients, which were obtained by applying a Sobel filter to the luminance channel (Y) whose values again range between 0 (black, no gradient) and 255 (white, high gradient). The edge structure was defined as the regions of strongest color contrast, and the associated fractal dimensions \(D_f\) for each painting were obtained. In this case, the \(D_f\) of these patterns showed decided grouping, unlike those of the physical paint blobs. A highly significant difference was found for Pollock's edges (\(D_f = 1.84\)) as compared to those of Les Automatistes (\(D_f = 1.48\)), \(F(1,14) = 14.52, p < 0.002\). The works of Jackson Pollock thus show highly irregular edge structures (characterized by \(D_f\) close to 2), compared with those of Les Automatistes, while Avital's edges possess very simple Euclidean or-
ganization (\(D_f\) roughly 1). It is therefore the irregularity of edges that makes Jackson Pollock's style unique and is rep-
resentative of the degree of "expressionism" in his painting.

The suggestion that patterns of similar fractal dimension are perceptually indistinguisable can be related to the work of Julesz [19], who argues that texture discrimination in "effortless" or "imme-
diate" perception can only occur for configurations whose autocorrelation power spectra are different. Such correlation statistics can be implicitly linked to the multifractal spectrum (e.g. \(D_f\) is equivalent to the two-point correlation exponent, a structural measure of "pair-clustering" between points on the image), and thus these conclusions pro-
vide a natural extension of earlier find-

The juxtaposition of blobs versus edges on the canvas provides two distinct structures in one painting. One facet of the image results from the deposits of raw pigment on the canvas, while another facet has as its origins the boundary between two adjacent colors. The similarity between these definitions and one of Julesz's fundamental classes of topologi-
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Mean \(D_f\) of blob and edge structure. (© J. Mureika)
mean fractal dimensions implies a “symmetry” between indistinguishable components that form a cohesive whole. However, for Les Automatistes, the density of edges is significantly less than the density for blobs. There is thus a breakdown in the structural symmetry in this case, yielding a perceptual “conflict” of two nested but distinguishable characteristics of the painting. Thus, for the Pollock paintings, the viewer makes effortless transitions between blobs and edges, but not so for Les Automatistes.

The contrast between edges and blobs has figured prominently in art-historical analysis as the “linear versus painterly dimension” discussed in Wolfflin [21]. While the linear is characteristic of classical art styles, which favor clear edges and structured space, the sketchy baroque and impressionist styles are more painterly, encouraging viewers to complete an image. The linear versus painterly dimension has also consistently emerged as the primary one underlying perceptual discriminations between pairs of paintings. This applies to paintings selected across a broad spectrum of traditions [22,23] as well as those produced by Avital’s systematic art approach [24].

In sum, this new study has shown that Jackson Pollock is unique within gestural expressionism because of the irregularity or degree of roughness of edges unifying the structure of his paintings. It is precisely the disposition of the brain to discriminate edges [25] that makes it so sensitive to this fractal property in Jackson Pollock paintings, the viewer makes discerned in seeming chaos, and this property of the whole implies that order or degree of roughness of edges unifying the structure of his paintings. Thus, for the Pollock’s Fractal Drip Paintings,” Nature 399 (3 June 1999) p. 422.


7. Taylor [4].


12. Mureika [10].

13. Taylor et al. [2].


15. Taylor [5].

16. Berlyne [14].


19. Julesz [6].


25. Labini et al. [9].

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