Authenticating Pollock Paintings Using Fractal Geometry

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Jackson Pollock's paintings are currently valued up to US$40M, triggering discussions that attribution procedures featuring subjective visual assessments should be complimented by quantitative scientific procedures. We present a fractal analysis of Pollock's patterns and discuss its potential for authenticity research.

Key Words: Abstract Art, Authenticity, Fractals, Jackson Pollock

1. Introduction

On a stormy night in March 1952, in a drunken, suicidal state the notorious Abstract Expressionist painter Jackson Pollock (1912-1956) laid down the foundations of his masterpiece Blue Poles: Number 11, 1952 by rolling a large canvas across the floor of his windswept barn and dripping fluid paint from an old can with a wooden stick (Varnedoe, 1998). The painting represented the culmination of ten years of development of his “drip and splash” technique. In contrast to the broken lines painted by conventional brush contact with the canvas surface, Pollock poured a constant stream of paint onto his horizontal canvases to produce uniquely continuous trajectories. This deceptively simple act fuelled unprecedented controversy and polarized public opinion around the world: was this primitive painting style driven by raw genius or was he simply a drunk who mocked artistic traditions? Twenty years later, the controversy was rekindled when the Australian government purchased the painting for two million U.S. dollars. In the history of Western art, only works by Rembrandt, Velázquez and da Vinci had commanded more 'respect' in the art market. Pollock's brash and energetic works continue to grab attention, as witnessed by the success of the retrospectives during 1998-99 (at New York's Museum
of Modern Art in New York and London's Tate Gallery) where prices of forty million dollars were discussed for *Blue Poles: Number 11, 1952*.

Appreciation of art is, of course, a highly subjective, personal judgment. Standing in front of one of Pollock's vast canvases (such as *Blue Poles: Number 11, 1952* shown in Figure 1), looking at the dense web of interweaving swirls of paint, no one can be told whether such imagery should be liked or not - least of all by a computer. A computer calculates the parameters of an object in a fundamentally different fashion than the human observer. People observe the many different parameters of the painting (for example, the size, shape, texture and color) all at once, capturing its 'full impact'. In contrast, the computer's approach is reductionist - it separates information and calculates each parameter in isolation. As a consequence, although a computer analysis can never tell you whether an artwork should be 'liked', it can tell you what the painted patterns 'are' with remarkable precision and objectivity. Its reductionist ability to scrutinize individual parameters allows it to quantify information that might have been lost in the 'full impact' witnessed by a human observer. The computer employs its superior computing power (calculating over three hundred megabytes of digitized information for the millions of patterns lying within a typical painting) and precision (examining patterns down to sizes of less than one millimeter) to quantify the painted patterns on a Pollock canvas. The computer can then perform a quantitative comparison of the pattern characteristics with those found in other Pollock paintings (in principle, this procedure could involve the entire catalog of known Pollock paintings (O'Connor and Thaw, 1951)). This computation is well beyond the fundamental capabilities of the human visual system.

This deconstruction of Pollock's paintings into mathematical parameters might at first appear to be of little use in the world of art, where human assessments such as beauty, expression and emotion seem more appropriate. However, as the commercial worth of Pollock's paintings continue to soar, judgments of authenticity have become increasingly critical. If a new drip painting is found, how do we decide if it is a long-lost masterpiece or a fake? When dealing with such staggering commercial considerations, subjective judgments attempting to identify what art scholars call the 'hand' of the artist - the tell tail visual trademarks - may no longer be fully adequate. In particular, subjective judgments have become increasingly difficult to defend against potential litigation. What is becoming clear is that subjective assessments should be coupled with more quantitative and objective scientific investigations. This is not, of course, a new proposal for authenticity studies. Investigations of paintings of unknown origin will often call on a
diverse range of consultants from the arts and sciences. From the arts, provenance studies (where an art historian will judge the painting’s history relative to known facts about the artist) will be coupled with connoisseurship (where an art expert will compare their visual inspection of the painting with the artist’s catalog of known paintings). From the sciences, a range of established techniques can be employed to date or determine the material composition of the paint, canvas and frame (McCrone, 2001).

For many artists, this combination of research tools yields compelling evidence for attributing paintings. Unfortunately, Pollock’s unique history adds uncertainty to these studies. For example, financial success arrived late in Pollock’s life leading him to give away paintings in exchange for groceries, etc (Naifeh and Smith, 1989; Potter, 1985). This complicates provenance judgments – long-lost Pollock paintings may exist where a clear historical link between the artist and the current owner (highly desired for establishing provenance) is beyond trace. Furthermore, Pollock was the subject of unprecedented publicity at his peak. Life magazine’s 1949 feature article on Pollock (Seiberling, 1949) was followed one year later by Hans Namuth’s (Namuth, 1980) film documentary, both of which exposed the details of Pollock’s drip and splash style to the public. The resulting wave of Pollock imitators is well-documented, providing proof of the existence of non-Pollock drip paintings dating from Pollock’s era and composed using similar paints and canvases. This limits scientific techniques that aim to distinguish paintings based on material composition and age. These complications emphasize the importance of the visual characteristics of the dripped patterns for authenticity research. In this article we discuss the scientific pattern recognition tools used in our consultancy work for private collectors and the International Foundation for Art Research, currently the main attribution body for Pollock paintings.

2. Fractals: the Hand of Pollock

What is the identifying 'hand' of Pollock? The surface of Blue Poles: Number 11, 1952 has been likened to a battlefield. The vast canvas, stretching across five meters from end to end, contains shards of broken glass embedded in the paint encrusted surface, blood stains soaked into the canvas fabric and eight splattered 'poles' violently imprinted by a plank of wood. With each clue shrouded in Pollock mythology, it is clear that an understanding of the essence of Pollock's work requires a rigorous distillation of fact from fiction. The most distinctive and important features of this epic work are, of course,
his trademark swirls of paint that evolved through six months of repetitive deposition (Naifeh and Smith, 1989). This cumulative painting process is strikingly similar to the way patterns in Nature arise - for example, the way leaves fall day after day to build a pattern on the ground, or the way waves crash repeatedly on the shore to create erosion patterns in a cliff face. In fact, during his peak years of 1947-52, the drip paintings were frequently described as 'organic' (Potter, 1985), suggesting that the imagery in his paintings alluded to Nature. Lacking the cleanliness of artificial order, his dripped paint clearly stands in sharp contrast to the straight lines, triangles, squares and the wide range of other 'human-made' shapes belonging to Euclidean geometry. But if Pollock's swirls of paint are indeed a celebration of Nature's organic shapes, what shapes would these be? What geometry do organic shapes belong to? Do objects of Nature, such as trees and clouds, have an underlying pattern, or are they 'patternless' - a disordered mess of randomness?

During Pollock's era, Nature's scenery was assumed to be disordered and his paintings were likewise thought to be random splatters devoid of order. However, since Pollock's time, two vast areas of study have evolved to accommodate a greater understanding of Nature's rules. During the 1960s, scientists began to examine the dynamics of Nature's processes - how natural systems, such as the weather, evolve with time. They found that these systems were not haphazard. Although natural systems appeared to be disordered, hidden underneath was a remarkably subtle form of order. This behavior was labeled as chaotic and an area of study called chaos theory was born to understand Nature's dynamics (Gleick, 1987). Whereas chaos describes the motions of a natural system, during the 1970s a new form of geometry, called the fractal, was proposed to describe the patterns that these chaotic processes leave behind (Mandelbrot, 1977). Since the 1970s many of Nature's patterns have been shown to be fractal. Examples include coastlines, clouds, flames, lightning, trees and mountain profiles. Fractals are referred to as a new geometry because the patterns look nothing like traditional Euclidean shapes. In contrast to the smoothness of artificial shapes, fractals consist of patterns that recur on finer and finer magnifications, building up shapes of immense complexity.

Given that Pollock's paintings are often described as 'organic', the obvious step towards identifying the 'hand' of Pollock is to take the pattern analysis techniques used to identify fractals in Nature's scenery and apply the same process to Pollock's canvases.
Nature's fractals obey statistical self-similarity - the patterns observed at different magnifications, although not identical, are described by the same spatial statistics (Mandelbrot, 1977). The traditional method for detecting statistical self-similarity is shown in the inset to Figure 2 for a schematic representation of *Blue Poles: Number 11, 1952*. A scanned photographic image of the painting is covered with a computer-generated mesh of identical squares. By analyzing which squares are occupied by the painted pattern (shaded blue in the inset) and which are empty, the statistical qualities of the pattern can be calculated. Reducing the square size in the mesh is equivalent to looking at the pattern at a finer magnification. Thus, in this way, the pattern's statistical qualities can be compared at different magnifications.

The analysis of *Blue Poles: Number 11, 1952* (actual size 210 by 486.8cm) uses a 42.0 by 97.4cm high-resolution photographic print of the painting as the source image. Our newly-updated analysis procedures employ a HP Designjet 815mfp scanner, which allows such an image to be scanned using a one step process. We note, however, for the results reported in this article, a scan-window limited to 42 by 42cm necessitated a two-step procedure as follows. First, a 42.0 by 42.0cm section of the print was scanned in at 1200dpi, creating a 24bit color bitmap image with 19842 pixels across each length. The analysis of this image examines pattern sizes ranging from the smallest speck of paint (0.8mm on the canvas) up to the height of the canvas (210cm). Within this size range, the analysis is not affected by any measurement resolution limits, such as those associated with the photographic or scanning procedures. For example, the pixel separation after scanning corresponds to a physical size of 0.1mm on the canvas, and thus the smallest painted pattern spans 8 pixels. Similarly, the graininess associated with the photographic process corresponds to the order of several pixels. A visual inspection confirms that the smallest analyzed pattern is undistorted. To analyze patterns across size scales larger than 210cm, including those spanning the entire canvas length of 486.8cm, a smaller photographic print (18.1 by 42.0cm) was required in order to fit the painting’s full image within the length of the scanner window (42cm). By combining the two sets of analysis, we find that the largest observed fractal pattern is over one thousand times larger than the smallest pattern (see below) (Taylor et al., 1999a; Taylor et al., 1999b). This size range is significantly larger than for observations of fractals in other typical physical systems (where the largest patterns are typically just twenty-five times larger than the smallest pattern) (Avnir et al., 1998). A consequence of observing the fractal patterns over such a large size range is that parameters that characterize the fractal statistics can be determined with great accuracy.
A crucial parameter in characterizing a fractal pattern is the fractal dimension, \( D \), and this quantifies the scaling relationship between the patterns observed at different magnifications (Mandelbrot, 1977). For Euclidean shapes the dimension is a simple concept and is described by the familiar integer values. For a smooth line (containing no fractal structure) \( D \) has a value of 1, while for a completely filled area its value is 2. However, for a fractal pattern, the repeating structure causes the line to begin to occupy area. \( D \) then lies in the range between one and two and, as the complexity and richness of the repeating structure increases, its value moves closer to 2. This is demonstrated in Figure 3 for example sections of Pollock’s paintings. The \( D \) value of a fractal pattern can be determined using the well-established “box-counting” technique (Gouyet, 1996; Mandelbrot, 1977). Specifically, if we count \( N \), the number of occupied squares (or “boxes”), as a function of \( L \), the square size, then for fractal behavior \( N(L) \) scales according to the power law relationship \( N(L) \sim L^{-D} \), where \( 1 < D < 2 \) (Gouyet, 1996; Mandelbrot, 1977). This power law generates the scale invariant properties that are central to fractal geometry. The \( D \) values, which chart this scale invariance, can be extracted from the gradient of the ‘scaling plot’ of \( \log(N) \) plotted against \( \log(L) \). The standard deviation associated with fitting the data to the fractal scaling behavior is such that \( D \) can be determined to an accuracy of 2 decimal places (Taylor, 2000; Taylor et al., 1999b).

We adopt two commonly used magnification procedures to construct the scaling plots and find them to be consistent. For the first procedure, the square size \( L \) is reduced iteratively using the inverse expression \( L = H/n \), where \( H \) is the canvas size and \( n \) is the number of iterations \((n = 1, 2, 3 \ldots)\). For the second procedure, the exponential expression \( L = H C^{-n} \) (where \( C \) is a selected magnification factor, for example 1.1) is applied iteratively. The first procedure has the advantage of generating a larger number of data points, while the second procedure reduces computation time and produces equally spaced points across the resulting log-log scaling plot. For both procedures, the validity of the counting procedure increases as \( L \) becomes smaller and the total number of boxes in the mesh is large enough to provide reliable counting statistics. In typical scaling plots of Pollock’s canvases, the number of boxes in the mesh ranges from 100 to 6.9 million, ensuring reliable counting statistics.

To date, we have used the box-counting procedure to analyze 17 Pollock paintings: *Composition with Pouring 11* (1943), *Water Birds* (1943), *Untitled* (1945),
Free Form (1946), Lucifer (1947), Full Fathom Five (1947), Number 14, 1948 (1948), Figure (1948), Number 23, 1948 (1948), Number 8, 1949 (1949), Number 27, 1950 (1950), Number 32, 1950 (1950), Autumn Rhythm: Number 30 (1950), Unknown (1950),Untitled (1951), Blue Poles: Number 11, 1952 (1952) and Convergence: Number 10, 1952 (1952). Independent analysis performed by another other research group (Mukeika et al., 2004) has confirmed the fractal character of Full Fathom Five (1947), Autumn Rhythm: Number 30, 1950 (1950) and Blue Poles: Number 11, 1952 (1950), along with six additional Pollock paintings: Reflections of the Big Dipper (1947), Number 1A, 1948 (1948), Number 1, 1949 (1949), Number 28, 1950 (1950), Number 31, 1950 (1950), and Lavender Mist: Number 1, 1950 (1950). This collection of 23 Pollock paintings spans the full variety of Pollock’s drip catalog: from his first drip attempts of 1943 up to his final, mature works of 1952, from one of his smallest paintings (48.9 by 35.5 cm of Free Form) to one of his largest canvases (266.7 by 525.8 cm of Autumn Rhythm: Number 30, 1950), and paintings created using different paint media (enamel, aluminum, oil, ink and gouache). We note that many Pollock’s paintings feature a number of different colored layers of paint. For these paintings, we electronically deconstruct the paintings into their constituent colored layers and perform a box-counting analysis on each layer. This color separation is performed by identifying the RGB range (on a scale of 0 to 255 for each of the red, green and blue channels) of the color variations within each layer and then filtering accordingly. For each of the Pollock paintings analyzed to date, all the constituent colored layers have been found to be fractal with well-defined D values.

When the first details of our fractal analysis of Pollock paintings were published in 1999 (Taylor et al., 1999a; Taylor et al., 1999b), we described his style as ‘Fractal Expressionism’ to distinguish it from computer-generated fractal art. Fractal Expressionism indicates an ability to generate and manipulate fractal patterns directly. The discovery raised a critical question: how did Pollock manage to paint such intricate patterns, so precisely, and to do so twenty-five years head of their scientific discovery in Nature? Remarkably, there are two revolutionary aspects to the drip and splash technique and both have potential to become chaotic and generate fractals (Taylor, 2000; Taylor, 2003a; Taylor et al., 1999b). The first concerns the fluid paint as it falls though the air. Although evidence can be found in early sketches made over a century ago by the British physicist Lord Rayleigh, it wasn’t until the 1990s that fast-photography techniques allowed systematic studies of fluid falling under gravity. These studies show that falling fluid can decompose into a sequence of fractal droplets (Shi et al., 1994). The second aspect concerns Pollock’s motions as he moved around the canvas. By abandoning the
need for brush contact with the canvas, Pollock freed up a diverse range of body motions. First investigated by the French mathematician Paul Lévy in 1936, recent preliminary studies reveal a form of fractal motion called ‘Lévy flights’ (Taylor, 2004) in the physiology of human motion.

These two fractal generation processes – the drip process and Pollock’s motions - operate across distinctly different length scales. These scales can be estimated from Namuth’s film and still photography of Pollock at work (Taylor, 2000; Taylor, 2003a; Taylor et al., 1999b). Based on the physical range of his body motions and the canvas size, his Lévy flights across the canvas are expected to cover the approximate length scales between 1cm and 2.0m. In contrast, the drip process is expected to shape trajectories over length scales between about 1mm and 5cm. The latter range has been calculated from variables that affect the drip process (such as paint velocity and the height the paint is dropped from) and the absorption of paint by the canvas (such as paint fluidity and canvas porosity). Given these two different length scales we would therefore expect the fractal analysis to reveal two different values of $D$ in the two different size ranges. This can be seen in Figure 2, which shows a fractal analysis of the aluminum layer of *Blue Poles: Number 11, 1952*. For small sizes the scaling plot follows one straight line (and hence one fractal behavior) and then crosses over to another straight line at the transition size marked $L_T$ (which, for the aluminum layer, has a value of 1.8cm). We call the dimensions extracted from the two gradients the drip fractal dimension, $D_D$, and the Lévy fractal dimension, $D_L$. An empirical study of analyzed Pollock paintings reveals the condition $D_L > D_D$ is always satisfied.

Having separated the component colored layers (and analyzed each for their fractal content), we can then re-construct a Pollock painting by re-incorporating the layers to build the complete pattern. As each of the colored layers is re-incorporated, the two fractal dimensions, $D_D$ and $D_L$, of the overall painting rise (Taylor, 2000; Taylor, 2003a). Thus the combined pattern of many colors has higher fractal dimensions than any of the single layer colors. For example, the fractal dimensions of the aluminum layer of *Blue Poles: Number 11, 1952* are $D_D = 1.63$ and $D_L = 1.96$, compared to the higher values of $D_D = 1.72$ and $D_L = 1.98$ for the complete painting (Taylor, 2000; Taylor, 2003a; Taylor et al., 1999b). Our studies show $D_D$ of the complete painting to be a particularly sensitive, and hence useful, parameter for investigating drip paintings. In particular, by analyzing Pollock's drip paintings over a decade (from 1943 to 1952) we can use $D_D$ to quantify the evolution in his fractal patterns. Art theorists categorize the evolution of
Pollock's drip technique into three phases (Varnedoe, 1998). In the 'preliminary' phase of 1943-45, his initial efforts were characterized by low $D_D$ values. An example is the fractal pattern of the painting *Untitled* from 1945, which has a $D_D$ value of 1.12 (see Figure 3). During his 'transitional phase' from 1945-1947, he started to experiment with the drip technique and his $D_D$ values rose sharply (as indicated by the first gradient in Figure 4). In his 'classic' period of 1948-52, he perfected his technique and $D_D$ rose more gradually (second gradient in Figure 4) to the value of $D_D = 1.7$. An example is *Autumn Rhythm: Number 30, 1950* (see Figure 3). During his classic period he also painted *Untitled* (see Figure 3) which has an even higher $D_D$ value of 1.89. However, he immediately erased this pattern (it was painted on glass) prompting the speculation that he regarded this painting as too complex and immediately scaled back to paintings with $D_D = 1.7$. This suggests that his ten years of refining the drip technique were motivated by a desire to generate fractal patterns with $D_D \sim 1.7$. We have proposed that the graph shown in Figure 4 can be used to date authentic Pollock paintings (Taylor et al., 1999a).

### 3. Authenticity studies

Our fractal analysis of the Namuth film and photographs (capturing the evolution of Pollock paintings at different stages of completion) reveals a remarkably systematic process (Taylor et al., 2003b). He started by painting localized islands of trajectories distributed across the canvas, followed by longer extended trajectories that joined the islands, gradually submerging them in a dense fractal web of paint. This process was very swift with the fractal dimensions of the painting rising sharply (Taylor et al., 2003b). He would then break off and later return to the painting over a period of several days (or, in the case of *Blue Poles: Number 11, 1952*, six months), depositing extra layers of different colored paint on top of this initial ‘anchor’ layer. In this final stage he appeared to be fine-tuning the $D$ values, with values rising by less than 0.05. Pollock's multi-stage painting technique was clearly aimed at generating high dimension fractal paintings (Taylor et al., 2003b). This deliberate and systematic process raises the question that perhaps fractals are not an inevitable consequence of dripping paint but are instead the result of Pollock’s specific style.

This intriguing speculation is supported by the fact that the two fractal generation processes – the drip process and his Lévy motions - depend critically on parameters relating to Pollock’s painting style. For example, the formation of fractal droplets
depends on the paint viscosity and the manner in which Pollock ‘launched’ the paint from his painting implement. If, for example, the paint was too fluid, or the drop distance was too short, then fractal drops would not form. Similarly, the Lévy flights are not an inevitable feature of human motion - our latest research indicates that this fractal character permeates human motion when people restore their balance (Taylor and Boydston, manuscript in preparation). This suggests that perhaps Pollock’s chaotic dashes across the canvas were performed in a state of controlled “off-balance”, and that he deliberately tuned into the fractal behavior of this underlying physiological process. Thus, the emerging science of his painting process predicts that it is possible to generate both fractal and non-fractal drip patterns, depending on the parameter conditions chosen by the artist. This is confirmed by our analysis of Pollock’s studio floor. The patterns created by the paint that missed the canvas are not fractal, emphasizing that Pollock’s fractals were a direct consequence of the way that he aimed the paint at the canvas - the fractals were a product of Pollock’s compositional technique. This concept is further supported by our studies in which a chaotic pendulum is made to drip paint onto a horizontal canvas (Taylor, 1998; Taylor, 2003a). When the chaos in the swinging motion is suppressed, the resulting drip paintings are devoid of fractal content (Taylor, 2002).

Fractal patterns are the product of the specific technique Pollock used to drip paint and all of the analyzed drip paintings have this fractal composition. In fact, the ‘hand’ of Pollock is more specific than fractality - we can identify trademark features of Pollock’s fractal patterns that all of the analyzed Pollock paintings possess. These trademarks combine to have a profound impact on the visual character of his work and are summarized as follows: (1) Pollock paintings are composed of two sets of fractal patterns (generated by the drip process and his Lévy motions), (2) these fractal patterns occur over distinct length scales. In particular, although the transitional length scale $L_T$ varies between Pollock paintings (depending on factors such as canvas size), $L_T$ always lies within a specific size range of several centimeters (in order to protect the potential of this procedure for authenticity research, the precise range of $L_T$ values observed for authentic Pollock paintings remains confidential), (3) each set of fractal patterns is well-described by a fractal dimension extracted from the gradient of the log-log scaling plot, (4) the condition $D_T > D_D$ is always satisfied (the exact relationship between $D_T$ and $D_D$ remains confidential for the above reasons), (5) if the painting is composed of a number of colored layers, each layer satisfies the previous 4 criteria, (6) the combined pattern of different layers is also fractal and satisfies the first 4 criteria.
For drip paintings of unknown origin, it is informative to perform a fractal analysis to determine if the above criteria are satisfied. To date we have analyzed ten drip paintings supplied to us by private collectors in the USA who believe the paintings to date from the Pollock era. None of these paintings have matched all six criteria. In the attempt to match to the criteria, the computer fits the scaling plot data to two straight lines (one for low $L$ values and the other for high) using the $L_T$ value as a free variable to minimize the standard deviation of the fit lines to the data. If the $L_T$ value obtained by the fitting procedure lies within the accepted $L$ range (criterion 2), then the other criteria are assessed. If the $L_T$ value fails to lie within the required range, the painting is given a “second chance”, for which the fitting procedure is repeated using $L_T = 3.0$ cm (the average $L_T$ value for all analyzed Pollock paintings). Using this “forced fit”, the remaining criteria are then assessed. Out of the ten paintings, only one painting didn’t require the forced fit procedure. An example painting of unknown origin is shown in Figure 5. Despite any superficial similarities with Pollock's work, this painting does not match the above criteria. The “forced-fit” analysis of the black layer is shown in Figure 6 (the standard deviation of the data from the fit lines is 0.060, compared to 0.019 for the equivalent fit of Figure 2).

4. Conclusions

We conclude by emphasizing that the results presented in this article are part of an on-going research project. However, the 23 authentic Pollock paintings analyzed to date have a 100% success rate in terms of their fractal content. This is in contrast to the 100% failure rate of the drip paintings of unknown origin sent to us by private collectors in the USA. These initial results suggest the potential for computers to detect the trademark characteristics of Pollock’s patterns. In addition to our research of Pollock paintings, other researchers have used computers to investigate artists as diverse as early Chinese figurative painters (Voss, 1998) and Vincent Van Gogh (Heingartner, 2004; Herik and Postma, 2000). We anticipate that computer analysis procedures will become part of a rapidly growing collection of scientific tools (which already includes, for example, X-ray, ultraviolet and infrared radiation techniques, and optical and electron-beam microscopy (McCrone, 2001)) employed by art researchers to investigate works of art. Other fascinating developments include forensics techniques such as fingerprint and DNA analysis. Such developments are a signal of the growing interplay between art and science.
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References:


Taylor, R.P. and Boydston, C., manuscript in preparation. Fractal Analysis of Human Motion During Balance Restoration.


Figures

Figure 1

*Blue Poles: Number 11, 1952* (enamel and aluminum paint on canvas, 210 by 486.8cm) was painted by Pollock in 1952 (The National Gallery of Australia, Canberra, Australia).

![Image of Blue Poles: Number 11, 1952](image)

Figure 2

The aluminum layer of Pollock’s painting *Blue Poles: Number 11, 1952* was analyzed by covering a scanned photograph with a computer-generated mesh and counting the number $N$ of squares that contain part of the painted pattern (shaded blue in the schematic diagram).
representation shown in the inset) as a function of square size $L$. The square size is reduced using the inverse expression $L = H/n$ (where $H$ is the canvas size and $n$ is the interaction number), producing over 1000 individual data in the range of $L$ shown. When $N$ is plotted against $L$, on log-log (base 10) axes, the data fall on a single line (the black line). As with all of the analyzed Pollock paintings, there are in fact two gradients, and hence two fractal dimensions. To demonstrate this we have drawn a blue straight line through the large $L$ data and a red line through the small $L$ data. The two dimensions are $D_D = 1.63$ at short lengths (red line) and $D_L = 1.96$ at longer lengths (blue line). The $L$ value at which the transition between $D_D$ and $D_L$ occurs is labeled $L_T$.

![Figure 3: Sections of Pollock’s drip paintings are shown as examples of fractal patterns with different $D$ values. Left to right: a smooth line ($D = 1$, non-fractal), the black layer of *Untitled*, 1945 ($D = 1.12$), the black layer of *Autumn Rhythm*, 1950 ($D = 1.66$), *Untitled*, 1950 ($D = 1.89$) and a black square ($D = 2$, non-fractal).]
Figure 4

Fractal dimension $D_D$ plotted as a function of the year the pattern was painted. The two lines serve as guides to the eye (see text for details).

Figure 5.

A drip painting of unknown origin (enamel on canvas, 70.0 by 111.8 cm).
Figure 6.

The scaling plot of \( \log(N) \) against \( \log(L) \) used to analyze the black paint layer of the painting shown in Figure 5. To generate the scaling plot, the square size is reduced using the exponential expression \( L = H C^n \), where \( C = 1.1 \) and \( n \) is the number of iterations. The blue and red lines represent the fit to the data, using a forced transition length of \( L_T = 3.0 \text{cm} \).