From Number to Canvas: The Influence of the Fibonacci Sequence in Painting

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Outline

Motivation and Overview: Mathematics and Painting

- Deep historical dialogue between mathematics and visual art: proportion, symmetry, geometry, perspective.
- Fibonacci sequence and Golden Ratio appear:
  - In nature (phyllotaxis, shells, branching).
  - In architecture and painting (Renaissance to modern art).
- Goal of this talk:
  - Connect rigorous mathematics with concrete paintings.
  - Show how recursion and proportion guide composition.

Motivation and Overview: What This Talk Is About

- The Fibonacci sequence as a *structural tool* in painting.
- Case studies from historical masters: Leonardo, Turner, Kandinsky, Cubism.
- Original artworks constructed with explicit Fibonacci patterns.
- Operator-theoretic and geometric viewpoints (frames, flows, fractals).
- Future directions: algorithmic art, VR, neuroaesthetics.

Motivation and Overview: Mathematical Painting

Informal idea

Mathematical painting = intentional use of mathematical structures, patterns and principles in creating and interpreting visual images.

- Discrete vs continuous structures.
- Local vs global geometric constraints.
- Deterministic rules vs creative variation.

Remark

Mathematical painting does not eliminate creativity; instead, it balances deterministic rules with artistic variation, allowing intuition and expression to work within a rigorous framework.

Historical Background: From Antiquity to Renaissance

- Classical geometry: Euclid, proportion, similar figures.
- Harmony of ratios in architecture and sculpture.
- Renaissance:
  - Linear perspective (Brunelleschi, Alberti).
  - Proportional canons (Pacioli's *Divina Proportione*).
- Divina Proportione (Divine Proportion) is a 1498 book by mathematician Luca Pacioli, illustrated by Leonardo da Vinci, that explores the golden ratio (ϕ) and its applications in art, architecture, and geometry, popularizing mathematical principles of beauty and harmony during the Renaissance. The work, composed in Milan and first printed in 1509, is divided into three parts, covering the golden ratio, Platonic solids, and perspective, and remains a key text at the intersection of art and science.
- Fibonacci sequence appears in Europe via Leonardo of Pisa in the 13th century.

What is the Golden Ratio?

- The golden ratio is the irrational number

$$\phi = \frac{1+\sqrt{5}}{2} \approx 1.618.$$

- It satisfies the defining proportion

$$\frac{a+b}{a} = \frac{a}{b} = \phi.$$

- This ratio appears naturally in geometry, algebra, and recursive processes.
- Used as a proportional guide in:
  - Architectural façades.
  - Human figure studies.
  - Compositional layouts.
- Not always explicit, but part of a general proportional culture.

Algebraic Properties of ϕ

- ϕ is the positive root of
$$x^2 = x + 1.$$
- Fundamental identities:
$$\phi^2 = \phi + 1, \qquad \frac{1}{\phi} = \phi - 1.$$
- These relations explain the self-similar and recursive nature of golden-ratio constructions.

The Fibonacci Sequence

- Defined recursively by

$$F_{n+1} = F_n + F_{n-1}, \quad F_1 = F_2 = 1.$$

- Sequence:

$$1, 1, 2, 3, 5, 8, 13, \ldots$$

- Ratios of consecutive terms satisfy

$$\frac{F_{n+1}}{F_n} \to \phi \quad \text{as } n \to \infty.$$

Golden Rectangles

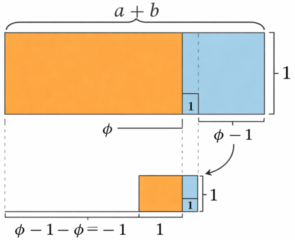
- A **golden rectangle** has side lengths in the ratio

$$\phi : 1,$$

where $\phi = \frac{1+\sqrt{5}}{2}$.

- Removing a unit square from a golden rectangle produces a **smaller golden rectangle**.

- This recursive removal leads to a **self-similar geometric construction**.

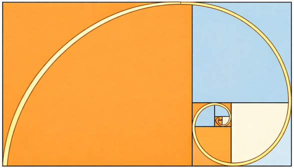


The Golden Spiral

- By drawing quarter-circles inside successive Fibonacci squares, we obtain an *approximate golden spiral*.

- The spiral is logarithmic and exhibits *scale invariance*: the same shape appears at every magnification.

- Artists use it as an *invisible compositional guide* to organize focal points, motion, and visual flow.

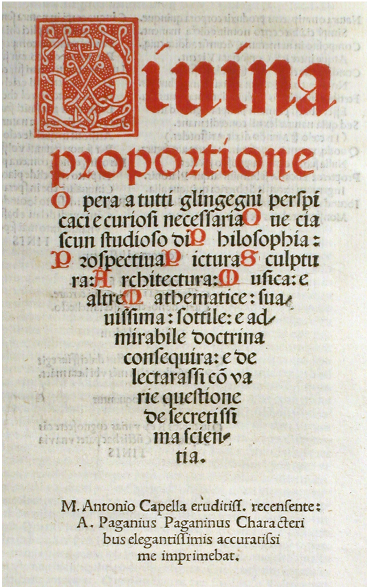


Golden Ratio in Nature

- The golden ratio appears in *phyllotaxis*, the arrangement of leaves, seeds, and petals.
- Spiral patterns in shells, sunflowers, and pinecones closely approximate *logarithmic spirals*.
- These configurations are believed to optimize packing efficiency, growth dynamics, and exposure to light.

Golden Ratio in Art

- Classical and Renaissance artists studied *proportion, symmetry, and harmony* as foundations of beauty.
- Luca Pacioli's *Divina Proportione* formalized the golden ratio as a mathematical and aesthetic principle.
- In practice, the golden ratio often serves as a *compositional guide* rather than a rigid or explicit rule.



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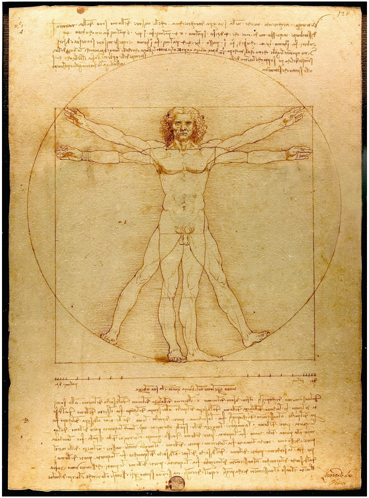
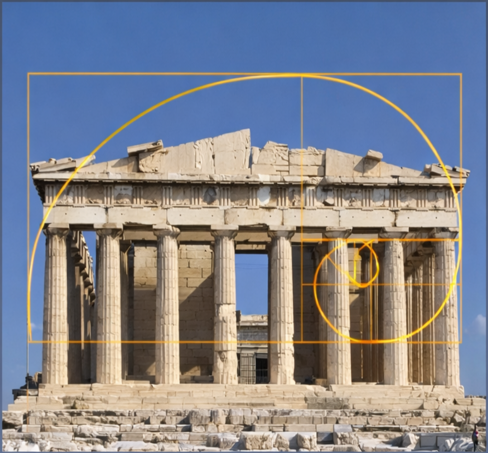
The Golden Ratio in the *Vitruvian Man*

- Leonardo places the human body simultaneously inside a **square** and a **circle**, representing rational order and natural harmony.
- The **navel** acts as a geometric pivot, dividing the height of the body in a proportion close to the golden ratio ϕ.
- Several body proportions (torso, limbs) exhibit *golden-section–like* relationships, reflecting recursive scaling.
- The golden ratio here functions as a **structural guide**, not an exact measurement rule.



The Golden Ratio in Architecture

- The Parthenon embodies ***balance and proportion***, core principles of classical aesthetics.
- Golden rectangles are used to guide the proportions of the Parthenon's facade.
- A golden *spiral* fits within the upper facade, reflecting recursive scaling.



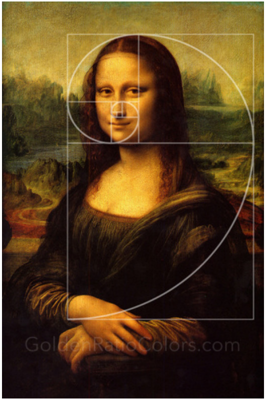
- While the golden ratio was not explicitly used, its principles underpin the design.

Modern Interpretations

- Fibonacci and golden-ratio structures appear in Cubism and abstraction.
- Artists such as Mario Merz explicitly incorporate Fibonacci numbers.
- Mathematics becomes a generative framework rather than a decorative element.
- The golden ratio provides a bridge between discrete recursion and continuous geometry, offering a mathematical framework that supports balance, harmony, and visual flow without restricting artistic freedom.

Historical Background: Leonardo da Vinci — Mona Lisa

- Spatial organization close to Golden Ratio divisions.
- Head, eyes, and hands aligned with golden rectangles or a Fibonacci spiral overlay.
- Suggests equilibrium through harmonic scaling.



Historical Background: Leonardo da Vinci — Mona Lisa

Leonardo's *Mona Lisa* (c. 1503–1517), housed in the Louvre Museum, is often cited as a paradigm of mathematical beauty in art. Numerous geometric analyses reveal that the spatial organization of the portrait approximates the Golden Ratio $\varphi \approx 1.618$, which is directly related to the Fibonacci sequence by

$$\lim_{n\to\infty} \frac{F_{n+1}}{F_n} = \varphi.$$

Historical Background: Turner: Geometry of Light

- J. M. W. Turner (1775–1851):
  - Professor of Perspective at the Royal Academy.
  - Systematic use of geometric construction.
- Works such as *Norham Castle, Sunrise* and *Frosty Morning*:
  - Horizon and key objects aligned near Golden Ratio lines.
  - Luminance modeled by an exponential decay $I(x) = I_0 e^{-kx}$.

"It is only when we are no longer fearful that we begin to create." — J. M. W. Turner

Historical Background: Turner: Norham Castle, Sunrise

Figure 1: Norham Castle, Sunrise.

- Horizon near $y = H/\varphi$.
- Castle placed at an approximate golden vertical.
- Light gradient approximates exponential decay.

"Light is therefore color." — J. M. W. Turner

Historical Background: Turner – Snow Storm (1842)

Figure 2: J. M. W. Turner, *Snow Storm – Steam-Boat off a Harbour's Mouth* (1842).

- Composition dominated by a large-scale spiral vortex.
- Visual flow follows an approximate logarithmic spiral

$$r(\theta) = ae^{b\theta},$$

guiding the viewer's eye inward.

- Contrast intensity increases toward the spiral center, modeling radial energy concentration.
- Ship placed near a high-curvature region, emphasizing instability.
- Suggests a dynamical system driven far from equilibrium.

Historical Background: Turner: Frosty Morning — Structural Analysis

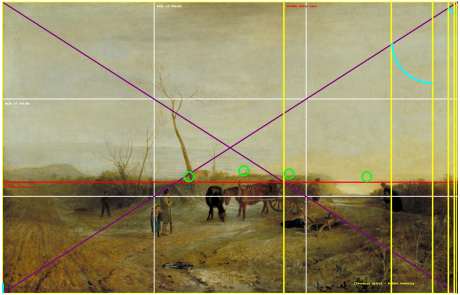


Figure 3: Golden rectangles, spiral and diagonals over Turner's *Frosty Morning*.

Historical Background: Turner: Frosty Morning — Interpretation

- Vertical and horizontal lines at $x = W/\varphi$, $y = H/\varphi$ pass through key narrative elements.
- Nested golden rectangles: $W, W/\varphi, W/\varphi^2, \ldots$ capture finer details.
- An approximate logarithmic/Fibonacci spiral tracks the viewing path:
  - Foreground $\rightarrow$ horse and cart $\rightarrow$ distant light.

The Fibonacci Sequence

Definition

$$F_{n+2} = F_{n+1} + F_n, \quad F_0 = 0,\ F_1 = 1.$$

$$0,\ 1,\ 1,\ 2,\ 3,\ 5,\ 8,\ 13,\ 21,\ 34, \ldots$$

- Appears in combinatorics, number theory, geometry, dynamics.
- Ratios F_{n+1}/F_n converge to the Golden Ratio.

Binet's Formula and Convergence

- Closed form:

$$F_n = \frac{\varphi^n - \psi^n}{\varphi - \psi}, \qquad \varphi = \frac{1+\sqrt{5}}{2},\ \psi = \frac{1-\sqrt{5}}{2}.$$

- As $n \to \infty$,

$$\frac{F_{n+1}}{F_n} \longrightarrow \varphi.$$

- Geometric interpretation: stable scaling factor for recursive constructions.

Matrix Representation

- Companion matrix

$$A = \begin{pmatrix} 1 & 1 \\ 1 & 0 \end{pmatrix}, \quad \begin{pmatrix} F_{n+1} \\ F_n \end{pmatrix} = A^n \begin{pmatrix} 1 \\ 0 \end{pmatrix}.$$

- Eigenvalues: φ and ψ.
- Links linear algebra, spectral theory, and growth.

Combinatorial Interpretations

- Domino tilings:
  - F_n counts tilings of a board with tiles of size 1 and 2.
- Binary strings:
  - F_{n+2} counts binary strings of length n with no two consecutive ones.
- Each interpretation suggests a way to "grow" a pattern recursively — very close to artistic construction.

Fibonacci, Substitution Dynamics, and Quasicrystals

- Substitution:

$$\sigma : a \mapsto (a, b), \quad b \mapsto a.$$

- Substitution matrix:

$$M_\sigma = \begin{pmatrix} 1 & 1 \\ 1 & 0 \end{pmatrix},$$

  same eigenvalues φ, ψ.
- Iteration leads to Fibonacci word and quasicrystal tilings.
- Provides a 1D model for self-similar structure in art and design.

Fibonacci in Nature

- Phyllotaxis: spiral counts on sunflowers, pinecones, etc.
- Spiral shells approximating logarithmic spirals.
- Branching of trees and leaf arrangements.
- These become geometric templates for composition.

Logarithmic Spiral and Golden Spiral

- Logarithmic spiral:

$$r(\theta) = ae^{b\theta}, \quad b = \frac{\ln \varphi}{\pi/2}.$$

- Golden spiral: special case where growth is tuned to φ.
- Approximated by quarter-circles in Fibonacci squares: $1, 1, 2, 3, 5, 8, \ldots$

Golden Rectangles in Classical Works

- Parthenon façade (approximate).
- Vitruvian-inspired figure studies.
- Later: explicit golden rectangles in Dalí's *The Sacrament of the Last Supper*.
- Provide a bridge from natural proportion to constructed art.

Golden Rectangles in Classical Works

Salvador Dalí, *The Sacrament of the Last Supper* (1955)

- Golden rectangles serve as compositional frameworks that balance symmetry and visual flow.
- In classical architecture and Renaissance figure studies, such proportions often appear implicitly as part of a broader proportional culture.
- Dalí's *The Sacrament of the Last Supper* is a rare example where the Golden Rectangle is used explicitly.
- The entire composition is inscribed within a golden rectangle, while smaller nested rectangles organize the table, figures, and architectural space. Mathematically, this creates a hierarchy of scales governed by the ratio φ, guiding the viewer's eye while preserving structural coherence.

Portrait of Salvador Dalí: Geometry and Surrealism

Portrait of Salvador Dalí — Oil on canvas,

- This portrait reinterprets Salvador Dalí through a surreal landscape organized by Golden Rectangle proportions.
- The face is implicitly inscribed in a golden rectangle, with the eyes positioned near horizontal divisions close to $1/\varphi$.
- Vertical elements—trees and cactus forms—align with approximate golden verticals, stabilizing the distorted scene.
- The white arch-like hair echoes a deformed golden spiral, guiding visual flow toward the eyes and nose.
- Repetition of elongated forms at different scales creates a φ-scaled hierarchy balancing symmetry and surreal deformation.
- The desert setting recalls Dalí's Catalan landscapes, while the geometric ordering reflects his fascination with mathematics, proportion, and classical harmony.

Kandinsky: Geometry of Abstraction

- *Point and Line to Plane* (1926):
  - Point = zero-dimensional nucleus.
  - Line = trajectory of a moving point.
  - Plane = field of interactions.
- Very close to a mathematical language of spaces and operators.
- Repeated circles, triangles, arcs $\Rightarrow$ quasi-fractal layering.

Composition VII vs Composition VIII

Figure 4: Composition VII (1913).

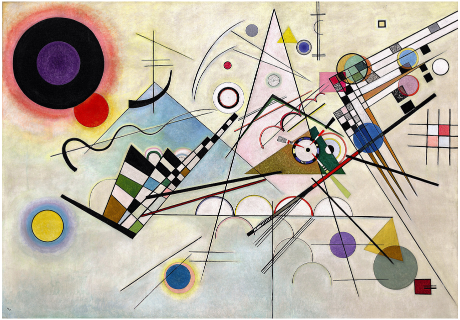


Figure 5: Composition VIII (1923).

Composition VII as a Nonlinear Flow

- Consider Hilbert space $H = L^2(\Omega; \mathbb{R}^3)$.
- Visual field evolves as

$$\varphi(t) = \Phi_t(\varphi_0),$$

  where $\{\Phi_t\}$ is a nonlinear flow on Ω.
- Sweeping arcs, gradients correspond to integral curves of vector fields and their superposition over time.

Composition VIII as an Affine Operator System

- Fix basic shapes $\{\varphi_j\}_{j=1}^{J}$ in H.
- Let G be semigroup generated by translations, rotations, anisotropic scalings.
- Painting modeled as

$$f(x) = \sum_{k=1}^{N} c_k \, U_k \varphi_{j(k)}(x),$$

with $U_k \in G$, $c_k \in \mathbb{R}^3$.
- The set $\{U_k \varphi_{j(k)}\}$ behaves like a structured frame for the span of the generators.

Spectral and Topological Structure

- Circular motifs $\approx$ eigenfunctions of radial operators.
- Intersecting lines $\approx$ interference of different modes.
- Curves in Composition VII trace vector-field trajectories.
- Abstract art as visualization of operator dynamics.

- Early Cubism influenced by:
  - Non-Euclidean geometry (Riemann, Poincaré).
  - Higher-dimensional polytopes (Jouffret).
  - Disseminated via Maurice Princet.
- Abandonment of single viewpoint in favor of many projections.

Cubist Multi-Projection Model

Model

For an object $X \subset \mathbb{R}^3$:

$$C(X) = \sum_{\theta \in \Theta} w(\theta)\, P_\theta(X),$$

where $P_\theta : \mathbb{R}^3 \to \mathbb{R}^2$ are projections and $\sum_\theta w(\theta) = 1$.

- Simultaneous, incompatible viewpoints overlaid.
- Equivalent to "shadows" of a higher-dimensional embedding.

Cubism and Frame Decompositions

- Let $H = L^2(\Omega)$ represent the image.
- Geometric atoms $\{\varphi_k\}$: triangles, quads, curved patches.
- Frame expansion:

$$f = \sum_k \langle f, g_k \rangle \varphi_k,$$

  with dual frame $\{g_k\}$.
- Redundancy mirrors robustness: partial erasure of facets doesn't destroy the composition.

Cubist Surfaces as Self-Affine Structures

- Repeated subdivision of planes into smaller, skewed facets.
- Visual effect similar to self-affine fractals.
- Provides a language to describe multi-scale complexity in Cubist compositions.

Cubist Portrait: Geometry, Fragmentation, and Perception

- This Cubist portrait represents the subject as a *decomposition into geometric facets* rather than a single viewpoint.
- The face is partitioned into planar regions, analogous to a decomposition of a surface into affine patches.
- Each fragment may be interpreted as a local transformation $T_i(x) = A_i x + b_i$, where rotations, scalings, and translations encode multiple perspectives.
- Overlapping grids and diagonals act like coordinate systems, breaking classical symmetry while preserving structural coherence.
- The eye, ear, and mouth appear at different orientations, reflecting simultaneous projections of a three-dimensional form.

Cubist Portrait — Oil on canvas, Shankhadeep Mondal

Where Mathematics Meets Art

Figure 6: Where Mathematics Meets Art (S. Mondal).

Analysis: Where Mathematics Meets Art

- Birds, clouds, and reflections grouped in Fibonacci sizes: $1, 2, 3, 5, 8, \ldots$.
- Tree branching follows recursion: new branch = sum of two preceding directions.
- Mountain peaks on an XY-grid with distances in ratio $1 : 1 : 2 : 3 : 5 : 8$.
- Boat lies along a Fibonacci-guided visual trajectory.

Fractal Geometry and Self-Similarity

- Iterated Function Systems (IFS):

$$T_i(x) = A_i x + b_i, \quad i = 1, \ldots, N,$$

  with contractions A_i.
- Fractal set F satisfies:

$$F = \bigcup_{i=1}^{N} T_i(F).$$

- Hausdorff dimension d from $\sum_i r_i^d = 1$ (Moran equation).

Fractal Geometry and Self-Similarity

An iterated function system consists of a finite collection of geometric rules, where each map applies a linear transformation such as scaling or rotation followed by a translation. The key assumption is that each map is contractive, so repeated application produces stable geometric structure.
The fractal set is defined as a fixed point of the union of these transformations: the entire set is composed of several smaller, transformed copies of itself. This is the mathematical formulation of self-similarity.
The Hausdorff dimension measures how densely the structure fills space across scales. It is often non-integer and is determined by the contraction ratios through the Moran equation.
In painting and Cubist abstraction, repeated subdivision, layered forms, and scale-recursive motifs behave visually like self-similar fractals, even when the artist does not compute them explicitly.

Fractal Measures and Visual Density

- Self-affine measure μ satisfies

$$\mu = \sum_{i=1}^{N} p_i \, \mu \circ T_i^{-1}.$$

- Support of μ resembles distribution of facets.
- Links harmonic analysis on fractals with visual density patterns.

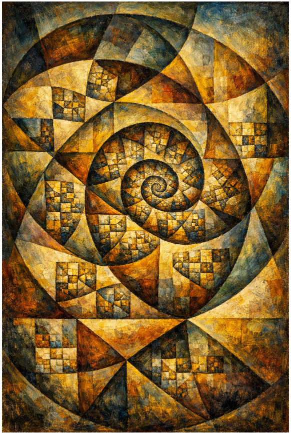
Example: Fractal Geometry and Self-Similarity in Painting

- This painting visualizes the idea of *self-similarity* arising from iterated function systems (IFS).
- Repeated geometric fragments appear at multiple scales, echoing the relation

$$F = \bigcup_{i=1}^{N} T_i(F),$$

where each transformation T_i produces a scaled copy of the whole.

- The spiral-like flow suggests recursive contraction, guiding the viewer's eye from coarse structures to finer details.



Fractal Geometry — Oil on canvas, Shankhadeep Mondal

Symmetry of the Infinite

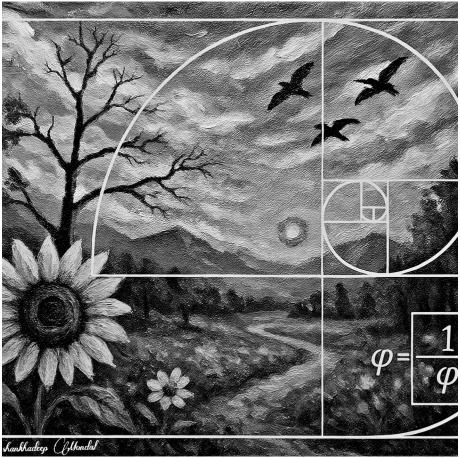


Figure 7: Symmetry of the Infinite (S. Mondal).

Analysis: Symmetry of the Infinite

- Sunflower: spiral counts in Fibonacci numbers.
- Tree branching again realizes $x_{n+1} = x_n + x_{n-1}$.
- Clouds, birds, and mountains arranged along a golden spiral.
- Path curvature and sun position aligned with φ-scaled divisions.

Solitude in the Geometry of Dreams

Figure 8: Solitude in the Geometry of Dreams (S. Mondal).

Analysis: Solitude in the Geometry of Dreams

- Moon and reflection: approximate symmetry across horizon line.
- Clouds resemble smoothed waveforms, modeled by oscillatory functions.
- Figures along the shore placed with gradually shrinking gaps, forming a non-uniform sequence $\{x_n\}$.
- Mathematics used as a subtle undercurrent to express emotion.

Mathematical Abstraction and Inner Ascent

This painting explores the idea of *ascent through fragmentation*. The human figure emerges from layered, flowing forms that suggest waves, roots, and broken architectural elements, symbolizing the interplay between structure and chaos.

The composition is governed by curved trajectories and diagonal forces, guiding the eye upward in a spiral-like motion. These paths echo mathematical ideas of growth, continuity, and transformation, reminiscent of recursive structures and energy flow.

Color contrasts—cool blues against warm earth tones—create a balance between stability and motion, while abstraction allows multiple

"How was the world created" by Shankhadeep Mondal.

Emotional Distance and Transition

This painting reflects a moment of emotional divergence, where two inner worlds move in different directions without confrontation.

The left side is grounded and enclosed—dark architectural forms and rooted elements suggest memory, attachment, and emotional weight. The male figure, with his hand near the heart, embodies introspection and unspoken feeling.

In contrast, the right side opens into an expansive horizon of sea and sky. The female figure moves toward light and space, rendered in softer tones, suggesting transition, freedom, or release. A fragile flowing connection links both worlds, symbolizing memory,

Estrangement

Symphony of Shapes

Figure 9: Symphony of Shapes by Shankhadeep Mondal.

Analysis: Symphony of Shapes

- Overlapping triangles, quadrilaterals, curves.
- Function $f \in L^2(\Omega)$ decomposed into atoms $\{\varphi_k\}$.
- Iterated affine maps T_i generate recursive subdivisions.
- Frames provide stable representation under facet “erasures”.

Life and War – A Cubist Composition

Figure 10: Life and War – A Cubist Composition (S. Mondal).

Analysis: Life and War

- Intersecting polygons encode conflict and fragmentation.
- Non-uniform scalings and rotations distort familiar forms.
- Multiple local symmetries create a complex visual topology.
- War interpreted as a perturbation of the usual metric structure of life.

Dissonance of the soul and Harmony in Chaos

Figure 11: Dissonance of the soul by Shankhadeep Mondal

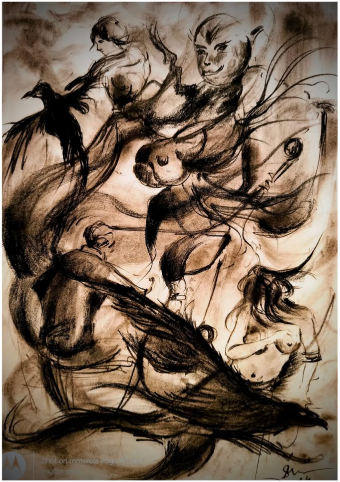


Figure 12: Harmony in Chaos by Shankhadeep Mondal

Golden Rectangles and Spirals in Practice

- Start from a Fibonacci tiling: squares of side $1, 1, 2, 3, 5, 8, \ldots$.
- Add quarter-circles to form an approximate golden spiral.
- Use this as an invisible scaffold for:
  - Focal points (faces, light sources).
  - Major contours (mountains, shorelines).
  - Color gradients and value transitions.

Algorithm for a Fibonacci Layout (1)

Algorithm

1. Choose an initial unit square.
2. Attach a second unit square to form a 1×2 rectangle.
3. For $n = 3, \ldots, N$:
   - Add a square of side $x_n = x_{n-1} + x_{n-2}$ in counterclockwise fashion.
4. Draw quarter-circles in each square to create a spiral.
5. Place main objects along high-curvature points of the spiral.
6. Align secondary elements with sides of the Fibonacci rectangles.
7. Adjust color, value, and texture along spiral directions.

Practical Design Variations

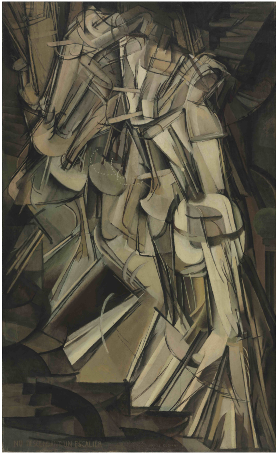
- Rotate or mirror the entire Fibonacci grid.
- Switch between exact Fibonacci sizes and "perturbed" ones.
- Combine multiple spirals with different centers.
- Hybrid constructions: Fibonacci spiral + Cubist facet subdivision.

Cubism Meets Fibonacci

- Many Cubist compositions exhibit implicit golden-ratio–based grids, even when not explicitly constructed.
- Sequential fragmentation, as seen for example in Duchamp's *Nude Descending a Staircase*, resembles recursive growth governed by the Fibonacci relation

$$x_{n+1} = x_n + x_{n-1}.$$

- In contrast, Mario Merz makes Fibonacci numbers and spirals explicit, embedding them directly into modular and architectural structures.



Nude Descending a Staircase (1912)

Fibonacci as a Structural Lens

- Use Fibonacci and φ to:
  - Analyze historical compositions.
  - Design new mathematical paintings.
  - Connect recursion, symmetry, and perception.
- Not a rigid rule, but a flexible organizing principle.

Perception and Neuroaesthetics

- Do viewers systematically prefer φ-based layouts?
- Mixed evidence in psychology and perception studies.
- Promising tools:
    - Eye-tracking on Fibonacci vs non-Fibonacci compositions.
    - Neuroimaging of responses to mathematically structured art.

Algorithmic and Digital Fibonacci Art

- Parametric design with Fibonacci grids and spirals.
- Iterated operator systems generating Cubist–fractal hybrids.
- Machine-learning models constrained by:
  - Fibonacci recursions.
  - Frame-theoretic stability.

Penrose Tilings and Non-Periodicity

- Penrose tilings built from shapes with φ-ratio edges.
- Non-periodic yet long-range ordered patterns.
- Natural companions to Fibonacci-based compositions:
  - Global order without translational symmetry.
  - Rich possibilities for mathematical painting.

Open Problems and Research Directions

- Formal "grammar" of recursive sequences in composition.
- Frame-theoretic robustness of visual decompositions under erasure.
- Classification of mathematical paintings via spectral data.
- Connections to quasicrystals, tilings, and operator algebras.

Conclusion

- Fibonacci sequence and Golden Ratio provide a unifying language for:
    - Historical art.
    - Modern abstraction.
    - New mathematical painting.
- Operator systems, frames, and fractals deepen this link.
- Ongoing dialogue between rigorous mathematics and creative practice.

Acknowledgment

This talk is based in part on work

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Thank You

Questions and discussion welcome.

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Thank You