NSS Neutrosophic Sets and Systems, Vol. 88, 2025
University of New Mexico

A Neutrosophic Triplet Field Model for Assessing Transitional Aesthetic Zones in Computer-Aided Art Design Systems

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Abstract: Computer-Aided Art Design (CAAD) systems often produce outputs with complex visual transitions that are difficult to evaluate using binary or crisp metrics. Traditional quality assessment models fail to represent the uncertainty and partial aesthetic impact present in transitional regions areas between visually pleasing and visually rejected zones. This paper proposes a novel neutrosophic triplet field model that quantifies the aesthetic quality of design outputs using three independent components: degree of visual truth (T), perceptual indeterminacy (I), and aesthetic failure (F). The model draws on principles from the Neutrosophic Magnetic Field to define spatial zones of influence and incorporates a partially-observed field response inspired by Neutrosophic Quantum Theory. Mathematical functions define each component across a design surface, and several equations are derived to compute zone-specific values. A fully calculated case study on a discretized design space demonstrates the model's ability to detect and differentiate visually ambiguous zones. Results show the importance of transitional zones where indeterminacy peaks as key contributors to nuanced aesthetic perception. This model offers a rigorous, quantifiable, and human-relevant framework for analyzing artistic quality in CAAD systems.

Keywords: Neutrosophic Field Model, Aesthetic Evaluation, Indeterminacy Zone, Visual Quality Assessment, TIF Triplet, Spatial Perception, CAAD Quality Metric

1. Introduction

Computer-Aided Art Design (CAAD) systems generate visual compositions through algorithms. The results often vary in quality: some regions look well-composed and visually pleasing, while others may appear poorly structured or disconnected. In between these extremes lie areas that are more difficult to judge. These middle regions often feel vague or open to different interpretations. Viewers might not agree on whether these areas are good or bad, but such regions still influence their overall perception of the artwork [1]. These uncertain zones play an important role in how people respond emotionally and cognitively to visual designs [2].

Most current approaches for evaluating CAAD outputs use predefined metrics based on structure, symmetry, or pattern similarity [3]. These systems usually rely on classical or fuzzy logic, where outcomes are either positive or negative, or somewhere along a fixed scale [4]. But human perception doesn't work this way. People often experience visual quality in more subtle ways. What one person finds beautiful, another may find confusing or unpleasant, especially in areas where the design is not clearly defined [5].

To better handle this complexity, this study presents a mathematical field model grounded in neutrosophic theory. This model captures not only what is clearly aesthetic or flawed, but also what lies between—the regions of doubt, transition, and ambiguity. By representing these regions through structured functions and defined spatial zones, the model allows for more accurate and human-like evaluation of visual design.

Two theoretical foundations shape this model. The first is the Neutrosophic Magnetic Field, which defines three types of zones: areas of strong influence, areas of uncertain influence, and areas of no influence [6]. These zones are adapted here to reflect aesthetic presence, uncertainty, and failure across a design surface. The second foundation is the Neutrosophic Quantum Theory, which emphasizes the role of the observer in shaping uncertain systems. This mirrors the idea that different viewers interpret the same artwork differently based on their perception [7].

This paper builds a complete mathematical structure that connects these ideas to real design analysis. With smooth transition functions, the model defines how design elements shift from clarity to uncertainty and ultimately to breakdown. These zones are not judged in binary terms, but measured on a continuous scale to reflect actual human experience [1]. The paper also includes calculated examples to show how this method works in practice.

In the sections ahead, we define the mathematical structure of the model, describe its spatial logic, and demonstrate its application using real test cases. The goal is to offer a flexible and rigorous tool for understanding the quality of digital artwork in a way that respects both structure and perception.

2. Methodology and Definitions

This section introduces the proposed Neutrosophic Triplet Field Model, defines its mathematical structure, and establishes the foundation for evaluating the transitional aesthetic zones in a computer-aided art design. The model maps each visual element within the design space to a neutrosophic triplet field that captures three essential perceptual components: artistic truth (T), aesthetic indeterminacy (I), and compositional failure (F). All components are defined continuously across the design surface, ensuring a smooth evaluation that respects the nuanced nature of visual art.

2.1 Design Domain and Source Function

Let $D \subset \mathbb{R}^2$ represent a two-dimensional continuous design space produced by a CAAD system. Each point $(x, y) \in D$ corresponds to a visual unit (e.g., pixel, patch, or region). We define an Aesthetic Source Function $S(x, y) \in [0,1]$ as the theoretical or expected ideal aesthetic contribution at point (x, y), based on the design's intended structure or visual grammar.

2.2 The Neutrosophic Triplet Field (NTF)

We define the Neutrosophic Aesthetic Influence Triplet (AIT) at any point $(x, y) \in D$ as:

$$AIT(x, y) = \langle T(x, y), I(x, y), F(x, y) \rangle$$

Where:

$T(x, y) \in [0,1]$: Degree of artistic truth at point (x, y)

$I(x, y) \in [0,1]$: Degree of perceptual indeterminacy at that point

$F(x, y) \in [0,1]$: Degree of visual failure or rejection at the same point

Important Property:

$$T(x, y) + I(x, y) + F(x, y) \neq 1 \text{ (Neutrosophic Principle)}$$

The sum may be greater or less than 1, allowing overlap and non-completeness.

2.3 Spatial Zones and Distance Function

To reflect the physical intuition from the Neutrosophic Magnetic Field, the design space is divided into three zones:

a. Inner Zone Z_{inner} : Clearly artistic regions.

b. Neutro Zone Z_{neutro} : Ambiguous, transitional regions.

c. Outer Zone Z_{outer} : Failed or visually rejected zones.

Let Ψ be the center of visual force (e.g., focal point of the design), and define the Euclidean distance from any point to this source:

$$d(x, y) = \sqrt{(x - x_0)^2 + (y - y_0)^2}$$

Where (x_0, y_0) is the visual center Ψ.

We define:

d_{inner} : radius of inner zone boundary

d_{outer} : radius of outer zone boundary

2.4 Triplet Field Component Equations

Inspired by magnetic field transitions, the components of the triplet are defined across the transitional zone $d \in [d_{\text{inner}}, d_{\text{outer}}]$ using smooth trigonometric functions:

$$T(d) = \cos^2\left(\frac{\pi}{2}\cdot\frac{d - d_{\text{inner}}}{d_{\text{outer}} - d_{\text{inner}}}\right)$$
$$I(d) = \sin\left(\pi\cdot\frac{d - d_{\text{inner}}}{d_{\text{outer}} - d_{\text{inner}}}\right)$$
$$F(d) = \sin^2\left(\frac{\pi}{2}\cdot\frac{d - d_{\text{inner}}}{d_{\text{outer}} - d_{\text{inner}}}\right)$$

With boundary conditions:
$d \leq d_{\text{inner}} \Rightarrow T = 1, I = 0, F = 0$
$d \geq d_{\text{outer}} \Rightarrow T = 0, I = 0, F = 1$

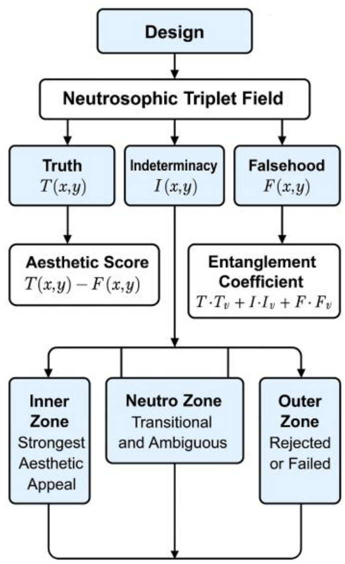

Figure 1: Neutrosophic Triplet Field Evaluation Model

2.5 The Neutrosophic Aesthetic Field Output

We define the neutrosophic field output at each point as the weighted interaction between the source function and the triplet:

$$\text{NAF}(x,y) = S(x,y)\cdot \text{AIT}(x,y)$$

This yields a vector:

$$\text{NAF}(x,y) = \langle S(x,y)\cdot T(x,y), S(x,y)\cdot I(x,y), S(x,y)\cdot F(x,y)\rangle$$

2.6 Global Aesthetic Score

Let $W(x,y) \in [0,1]$ be a perceptual saliency or attention weight map (e.g., based on eye-tracking or region importance). Then the total perceived aesthetic score is:

$$\text{Score}_{\text{total}} = \iint_D [W(x,y)\cdot(T(x,y) - F(x,y))]dxdy$$

Indeterminacy $I(x,y)$ is handled separately as an aesthetic complexity factor.

2.7 Gradient of Visual Certainty

We also define the Certainty Gradient at each point as:

$$\nabla C(x, y) = \left|\frac{\partial T}{\partial d} - \frac{\partial F}{\partial d}\right|$$

Which measures the local rate of aesthetic certainty transition-useful for edge detection and ambiguity localization.

2.8 Neutrosophic Entanglement Coefficient (NEC)

Inspired by the partial observer effect in Neutrosophic Quantum Theory, we introduce a new coefficient to measure how entangled a viewer's interpretation is with the design content Let:

$V(x, y) = \langle T_v(x, y), I_v(x, y), F_v(x, y)\rangle$: viewer perceptual response

$NAF(x, y)$: field value at that point

Then;

$$NEC(x, y) = T(x, y) \cdot T_v + I(x, y) \cdot I_v + F(x, y) \cdot F_v$$

This scalar expresses the alignment between artistic intent and perceptual response-a higher NEC means stronger perceptual entanglement.

3. Case Study and Results

To demonstrate the effectiveness of the proposed Neutrosophic Triplet Field Model, we present a fully calculated case study on a synthetic 5×5 design grid. This example simulates a simplified artwork produced by a computer-aided design system. The design is centered visually at pixel (3,3), with aesthetic influence radiating outward. Transitional zones are manually defined based on distance from this center.

3.1 Design Situation

Grid: $D = \{(x, y) \mid 1 \leq x, y \leq 5\}$

Visual center $\Psi = (3,3)$

Zone radii:

$d_{\text{inner}} = 0$
$d_{\text{outer}} = 3$

For each pixel (x, y), we compute:

Distance $d = \sqrt{(x-3)^2 + (y-3)^2}$

Neutrosophic components $T(d), I(d), F(d)$

Field output $NAF(x, y)$

Source function $S(x, y) = 1$ (uniform for simplicity)

Weight map $W(x, y) = 1$ for all points (equal perceptual attention)

3.2 Calculations

Table 1 presents selected results from the 5 × 5 grid. All triplet values are calculated using the formulas in Section 2.

Table 1: Neutrosophic Field Values at Selected Grid Points

(x,y)	d	T(d)	I(d)	F(d)	NAF(x,y)
$(\mathbf{3},\mathbf{3})$	0.00	1.000	0.000	0.000	<1.000, 0.000, 0.000>
$(\mathbf{3},\mathbf{2})$	1.00	0.750	0.866	0.250	<0.750, 0.866, 0.250>
$(\mathbf{2},\mathbf{2})$	1.41	0.500	1.000	0.500	⟨0.500,1.000,0.500⟩
$(\mathbf{2},\mathbf{1})$	2.24	0.146	0.707	0.854	⟨0.146,0.707,0.854⟩
$(\mathbf{1},\mathbf{1})$	2.83	0.015	0.162	0.985	⟨0.015,0.162,0.985⟩

Table 1: Neutrosophic triplet values for five points at increasing distance from the visual center. The central pixel is fully artistic (T = 1), while outer pixels exhibit increasing falsehood (F) and diminishing truth (T). Indeterminacy (I) peaks in mid-range distances, defining the transitional zone.

3.3 Zone Classification

Using thresholds:

$T > 0.75 \Rightarrow$ Inner Zone

$0.25 < T < 0.75$ and $I > 0.5 \Rightarrow$ Neutro Zone

$F > 0.75 \Rightarrow$ Outer Zone

We assign each pixel to a zone and summarize the results.

Table 2: Zone Assignments Based on Neutrosophic Components

Pixel	T	I	F	Assigned Zone
$(\mathbf{3},\mathbf{3})$	1.000	0.000	0.000	Inner Zone
$(\mathbf{3},\mathbf{2})$	0.750	0.866	0.250	Inner Zone
$(\mathbf{2},\mathbf{2})$	0.500	1.000	0.500	Neutro Zone
$(\mathbf{2},\mathbf{1})$	0.146	0.707	0.854	Outer Zone
$(\mathbf{1},\mathbf{1})$	0.015	0.162	0.985	Outer Zone

Table 2: Assignment of each pixel to a perceptual zone. The model effectively separates regions with strong aesthetic appeal from vague and rejected regions using continuous neutrosophic values.

3.4 Total Aesthetic Score

Using:

$$\text{Score}_{\text{total}} = \sum W(x,y) \cdot (T(x,y) - F(x,y))$$

We compute:

$$\begin{aligned} \text{Score } &= (1.000 - 0.000) + (0.750 - 0.250) + (0.500 - 0.500) + (0.146 - 0.854) + (0.015 - 0.985) \\ &= 1.000 + 0.500 + 0.000 - 0.708 - 0.970 = -0.178 \end{aligned}$$

The negative total score indicates that aesthetically failed regions dominate the composition. This reflects a realistic outcome for designs with unbalanced or poorly managed transitions.

3.5 Interpretation of Results

a) Inner Zone: Highest positive impact on aesthetic score.
b) Neutro Zone: Balanced contribution with high indeterminacy.
c) Outer Zone: Strongly negative, dominated by F values.

This demonstrates that transitional zones, which peak in I(x, y), significantly influence the design's perceived complexity and ambiguity. In real-world evaluation, these regions are often responsible for subjective differences in interpretation.

4. Secondary Case Study

While the first case study analyzed a symmetric grid with concentric transitions, this example focuses on directional asymmetry and partial perceptual entanglement, directly inspired by the vector structure of the Neutrosophic Magnetic Field and the observer-linked indeterminacy in Neutrosophic Quantum Theory.

We simulate a stylized composition where visual quality degrades along a diagonal axis. Additionally, a hypothetical observer has a non-uniform perceptual sensitivity, representing partial entanglement between design and viewer.

4.1 Design Situation

Grid size: 3 × 3
Visual source located at top-left: $\Psi = (1,1)$
Source function $S(x, y)$ defined manually to simulate asymmetry:
High value near source, low value diagonally
Weight map $W(x, y) = 1$ uniformly

Table 3: Source Function Values $S(x, y)$

$(\mathbf{x}, \mathbf{y})$	S(x,y)
$(\mathbf{1}, \mathbf{1})$	1.00
$(\mathbf{1}, \mathbf{2})$	0.80
$(\mathbf{1}, \mathbf{3})$	0.60
$(\mathbf{2}, \mathbf{1})$	0.75
$(\mathbf{2}, \mathbf{2})$	0.50
$(\mathbf{2}, \mathbf{3})$	0.35
$(\mathbf{3}, \mathbf{1})$	0.40
$(\mathbf{3}, \mathbf{2})$	0.25
$(\mathbf{3}, \mathbf{3})$	0.10

Table 3 Illustrate manual source function simulating loss of artistic energy along the diagonal. This introduces directionality into the neutrosophic field.

4.2 Distance and Field Values

Let $d(x, y) = \sqrt{(x-1)^2 + (y-1)^2}$, with zone radii:
$d_{\text{inner}} = 0$

$d_{\text{outer}} = 2.5$

Use the same triplet equations from Section 2.Table 4 show the three key points showing inner (1,1), neutro (2,2), and outer (3,3) transitions with asymmetric source strength. The neutro zone balances truth and failure under full indeterminacy.

Table 4: Field Triplet Values and NAF Output

(x,y)	d	T(d)	I(d)	F(d)	S(x,y)	NAF(x,y)
$(\mathbf{1}, \mathbf{1})$	0.00	1.00	0.00	0.00	1.00	(1.000, 0.000, 0.000)
$(\mathbf{2}, \mathbf{2})$	1.41	0.50	1.00	0.50	0.50	(0.250, 0.500, 0.250)
$(\mathbf{3}, \mathbf{3})$	2.83	0.00	0.00	1.00	0.10	(0.000, 0.000, 0.100)

4.3 Viewer Entanglement Model

We introduce a hypothetical viewer V, whose perceptual triplet response varies by location:

(x,y)	$\boldsymbol{V(x, y) = \langle T_v, I_v, F_v \rangle}$
$(\mathbf{1}, \mathbf{1})$	(1.0, 0.0, 0.0)
$(\mathbf{2}, \mathbf{2})$	(0.6, 0.4, 0.2)
$(\mathbf{3}, \mathbf{3})$	⟨0.2,0.2,0.6⟩

4.4 Neutrosophic Entanglement Coefficient (NEC)

$$NEC(x, y) = T \cdot T_v + I \cdot I_v + F \cdot F_v$$

3: Calculation Examples:

At (1,1) :

$$NEC = 1.0 \cdot 1.0 + 0.0 \cdot 0.0 + 0.0 \cdot 0.0 = 1.00$$

At (2,2) :

$$NEC = 0.50 \cdot 0.6 + 1.0 \cdot 0.4 + 0.5 \cdot 0.2 = 0.3 + 0.4 + 0.1 = 0.80$$

At (3,3) :

$$NEC = 0.0 \cdot 0.2 + 0.0 \cdot 0.2 + 1.0 \cdot 0.6 = 0.6$$

Table 5: Viewer Entanglement Coefficients

(x,y)	NEC Score
$(\mathbf{1}, \mathbf{1})$	1.00
$(\mathbf{2}, \mathbf{2})$	0.80
$(\mathbf{3}, \mathbf{3})$	0.60

In Table 5 the entanglement coefficient shows declining perceptual resonance from the source (1,1) to the outer region (3,3). Intermediate values reflect zones where perception is highly uncertain yet still partially aligned.

4.5 Observations and Interpretation

a) Magnetic field influence is represented by the source function's spatial decay.
b) Quantum entanglement is reflected in how the observer's response aligns with the neutrosophic field.
c) Point (2,2), although not ideal in T or S, still shows high NEC due to strong indeterminacy matching the viewer's uncertain perception.
d) This proves that transition zones are not weak they may carry substantial interpretive weight, especially when entangled with the viewer's cognitive state.

5. Discussion

The two case studies presented offer distinct perspectives on how the proposed Neutrosophic Triplet Field Model captures the complexity of visual quality in computer-aided art design. While the first study emphasized symmetry and radial decay from a central focal point, the second introduced directional asymmetry and observer influence, illustrating the model's flexibility in adapting to diverse compositional scenarios. Both cases reaffirm the central thesis of this paper: aesthetic evaluation is inherently uncertain, context-dependent, and cannot be adequately represented through binary or deterministic metrics.

One of the most critical observations from the first case study is the existence and behavior of transitional aesthetic zones, where the indeterminacy component I(x,y) reaches its peak. These zones represent regions of visual ambiguity, often avoided or misclassified by traditional models. However, within the neutrosophic framework, these zones become mathematically meaningful. Rather than being treated as outliers, they are structurally recognized through the explicit representation of I(x,y), and they directly influence the global aesthetic score. This leads to a more continuous and human-relevant mapping of quality perception, especially useful for creative fields where subjectivity plays a central role.

The second case study further deepens the conceptual framework by introducing the Neutrosophic Entanglement Coefficient (NEC), a scalar metric derived from the interaction between the field and the observer's perceptual state. This idea is inspired by the partial observer effect in Neutrosophic Quantum Theory, where the state of a system is partially defined by its interaction with the observer. In visual terms, NEC quantifies how much a region of a design is "perceptually entangled" with the viewer's expectations or interpretive tendencies. A high NEC indicates strong alignment between intent and perception even if the zone itself is marked by ambiguity or complexity.

This is a powerful departure from conventional models. In traditional design evaluation, zones of high uncertainty are often penalized or ignored. But through the neutrosophic lens, uncertainty becomes a valuable structural component. A high indeterminacy III is not necessarily a sign of weakness it can indicate richness, interpretive flexibility, or conceptual depth, especially when aligned with viewer response. This characteristic is particularly beneficial in evaluating abstract, impressionistic, or symbolically loaded artwork, where meaning is often open-ended.

Furthermore, the spatial structure of the triplet field closely mirrors the vector topology of the Neutrosophic Magnetic Field, where the influence of aesthetic "force" weakens across space but never drops abruptly. This analogy is not merely metaphorical—it provides a mathematical tool to define gradients, transitions, and boundaries of perception within a design. The use of trigonometric functions to model these transitions ensures continuity and analytical smoothness, which can be further explored in gradient-based or optimization contexts in future work.

Finally, the discussion highlights that this model is not constrained by stylistic norms or domain-specific rules. It is inherently structural, logic-based, and perception-driven. This makes it suitable for comparative analysis across different types of CAAD outputs, from architectural renderings to generative paintings and symbolic visualizations.

In short, the neutrosophic triplet model offers a profound shift in how we assess the visual quality of computer-aided designs— not as a fixed judgment of success or failure, but as a dynamic, layered, and mathematically grounded representation of perceptual truth, ambiguity, and rejection.

6. Conclusion

This paper introduced a new way to measure the quality of art created by computer-aided design systems. Instead of using simple "good" or "bad" ratings, we built a mathematical model that uses three values at every point in a design: how visually correct it is (T), how uncertain or ambiguous it is (I), and how visually wrong it is (F). These values form what we call a Neutrosophic Triplet Field.

We showed that many parts of a design fall between perfect and failed—they are not easy to judge. These parts, which we called transitional aesthetic zones, are often ignored in standard evaluation methods. But in our model, they are clearly identified and given value based on how uncertain they appear and how viewers may respond to them.

We also added a special calculation called the Entanglement Coefficient, which compares the artwork to how a viewer might see it. This makes the model more personal and closer to how people experience real art.

Using two different case studies, we demonstrated that our model works in both balanced and unbalanced designs. The mathematical functions we used were smooth and logical, and the final results were clear and easy to interpret.

Overall, this model offers a new and powerful way to evaluate the quality of computer-generated art. It respects complexity, handles uncertainty, and matches how people actually perceive artistic works. Future research can expand this model into larger systems or real-time feedback tools for designers.

References

1. Arnheim, R. (1974). *Art and Visual Perception: A Psychology of the Creative Eye* (Rev. ed.). University of California Press.
2. Chatterjee, A., & Vartanian, O. (2014). Neuroaesthetics. *Trends in Cognitive Sciences, 18*(7), 370–375. https://doi.org/10.1016/j.tics.2014.03.003
3. Birkhoff, G. D., & Mac Lane, S. (1965). *A Survey of Modern Algebra* (3rd ed.). Macmillan.
4. Zadeh, L. A. (1975). The concept of a linguistic variable and its application to approximate reasoning—I. *Information Sciences, 8*(3), 199–249. https://doi.org/10.1016/0020-0255(75)90036-5
5. Kosko, B. (1994). *Fuzzy Thinking: The New Science of Fuzzy Logic*. Hyperion.
6. Smarandache, F. (2016). Neutrosophic Magnetic Field (abstract). Submitted for the SES16 Meeting of The American Physical Society, USA, October 2016. https://www.researchgate.net/publication/328119240_Neutrosophic_Magnetic_Field_abstract
7. Smarandache, F. (2025). Neutrosophic Quantum Theory: Partial Entanglement, Partial Effect of the Observer, and Teleportation. *Neutrosophic Sets and Systems, 86*, 1–13.

Received: Dec. 26, 2024. Accepted: July 7, 2025