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A Neutrosophic Epistemic Framework for Intangible Cultural Heritage Resources: Modeling Authenticity, Uncertainty, and Fragmentation in Tourism Development Potential Analysis

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Abstract: The sustainability of intangible cultural heritage (ICH) increasingly depends on its interface with cultural tourism. While this interaction brings visibility and economic benefit, it often introduces epistemic tension: different stakeholders interpret the same heritage in conflicting ways, with diverging views of authenticity, uncertainty, and threat. Conventional models grounded in fuzzy or static neutrosophic logic are insufficient to capture the dynamic, evolving nature of these perceptions. This study proposes a novel neutrosophic epistemic framework designed to evaluate ICH within tourism systems by modeling three distinct phenomena: (1) identity drift, where perceptions of authenticity change over time; (2) uncertainty accumulation, which captures the growing ambiguity of stakeholder consensus; and (3) narrative fragmentation, a condition in which stakeholder interpretations diverge beyond coherence. These processes are formalized using newly defined mathematical constructs, including a Neutrosophic Identity Drift Function (NIDF), an Epistemic Uncertainty Accumulation Function (EUAF), and a Structural Collapse Warning Score (SCWS). Each construction is precisely defined and demonstrated with computational examples.

1. Introduction

ICH represents a living repository of collective identity, practiced and transmitted across generations. Unlike material heritage, ICH is dynamic, context-dependent, and often situated in performance, memory, or oral transmission. With the expansion of cultural tourism, many ICH forms are increasingly mediated through commercial, political, and digital infrastructures. While these forces can support preservation, they also introduce epistemic instability what is seen as authentic, valuable, or threatened varies dramatically between stakeholders [1-2].

Current models for evaluating the condition or sustainability of ICH in tourism contexts often rely on fuzzy logic, expert scoring, or aggregate stakeholder surveys. These approaches typically treat perceptions as static inputs [3]. They do not model how perceptions shift over time, how uncertainty grows in the system, or how stakeholder disagreement becomes structurally significant [4]. Yet these processes drift, accumulation, and fragmentation are central to the actual risks that heritage systems face in tourism economies.

This paper proposes a dynamic neutrosophic epistemic framework that models ICH systems not as fixed entities but as temporally evolving structures of perception. We define three mathematical constructs to capture critical phenomena: (1) the Neutrosophic Identity Drift Function (NIDF), measuring the rate of change in perceived authenticity and distortion; (2) the Epistemic Uncertainty Accumulation Function (EUAF), capturing how ambiguity increases across time or stakeholders; and (3) the Structural Collapse Warning Score (SCWS), which integrates these metrics into a real-time signal of systemic vulnerability.

This framework is designed to serve both theoretical and applied objectives. Theoretically, it extends neutrosophic logic into a dynamic, multi-actor epistemic domain. Practically, it equips heritage professionals and policy institutions with quantitative tools for early warning, conflict diagnosis, and sustainability tracking. The model is demonstrated using simulated stakeholder data, but the formalism is generalizable across heritage contexts.

2. Neutrosophic Epistemic Modeling Framework

Let H be an intangible cultural heritage element evaluated at discrete time points $t \in \mathbb{N}$. Let $S_i, i = 1,2, \dots, n,$ denote the stakeholder groups involved in perceiving or interacting with H, such as local practitioners, tourists, and cultural authorities [5-6].

Each stakeholder provides, at each time t, a perception of the heritage in the form of an Interval Neutrosophic Evaluation:

$$H_i(t) = (T_i(t), I_i(t), F_i(t))$$

where:

$$T_i(t) = \left[T_{i,L}(t), T_{i,U}(t)\right], I_i(t) = \left[I_{i,L}(t), I_{i,U}(t)\right], F_i(t) = \left[F_{i,L}(t), F_{i,U}(t)\right]$$

These represent degrees of perceived authenticity, indeterminacy, and distortion respectively, as interpreted by each stakeholder group.

2.1. Stakeholder Volatility Functions

We define instantaneous volatility as the magnitude of temporal change in perceived value across all three components:

$$\mathrm{VOL}_i(t) = \sqrt{\left(T_{i,U}(t) - T_{i,U}(t-1)\right)^2 + \left(I_{i,U}(t) - I_{i,U}(t-1)\right)^2 + \left(F_{i,U}(t) - F_{i,U}(t-1)\right)^2}$$

These scalar expresses how unstable a stakeholder's view is from one time step to the next.

To capture total system volatility:

$$\mathrm{VOL}_{\mathrm{avg}}(t) = \frac{1}{n}\sum_{i=1}^{n} \mathrm{VOL}_i(t)$$

2.2. Identity Drift Sensitivity Index (IDSI)

ICH elements under heavy tourism influence often exhibit hypersensitivity in how authenticity is perceived. We define:

$$\mathrm{IDSI}_i(t) = \frac{\left|T_{i,U}(t) - T_{i,L}(t)\right|}{\left|T_{i,U}(t) - F_{i,U}(t)\right| + \epsilon}$$

where ϵ is a small positive constant to avoid division by zero. High values of IDSI indicate instability in identity anchoring-a critical signal in tourism contexts where "staged authenticity" may emerge.

2.3. Cross-Stakeholder Fragmentation Index (CSFI)

To measure the interpretive disagreement across stakeholders, we introduce:

$$\mathrm{CSFI}(t) = \frac{1}{n(n-1)}\sum_{i=1}^{n}\sum_{j\neq i} D_{ij}(t)$$

with divergence defined as:

$$D_{ij}(t) = \left\|T_{i,U}(t) - T_{j,U}(t)\right\| + \left\|F_{i,U}(t) - F_{j,U}(t)\right\| + \left\|I_{i,U}(t) - I_{j,U}(t)\right\|$$

3. Computational Example

Consider an ICH system: a traditional musical performance originally practiced in a local community, now adapted for an international cultural tourism festival. We evaluate it through two steps: before and after its integration into the tourism platform. Three stakeholder groups are surveyed:

S_1 : Local performers

S_2 : Foreign tourists

S_3 : Government cultural officers

Each group reports their perception of the heritage using upper bounds of the interval neutrosophic components at $t = 1$ and $t = 2$.

Step 1: Input Data

At time $t = 1$ (before tourism exposure):

$$\begin{aligned} T_{1,U}(1) = 0.95, \quad I_{1,U}(1) = 0.10, \quad F_{1,U}(1) = 0.05 \\ T_{2,U}(1) = 0.70, \quad I_{2,U}(1) = 0.25, \quad F_{2,U}(1) = 0.10 \\ T_{3,U}(1) = 0.80, \quad I_{3,U}(1) = 0.15, \quad F_{3,U}(1) = 0.10 \end{aligned}$$

At time $t = 2$ (after tourism exposure):

$$\begin{aligned} T_{1,U}(2) = 0.75, \quad I_{1,U}(2) = 0.30, \quad F_{1,U}(2) = 0.20 \\ T_{2,U}(2) = 0.90, \quad I_{2,U}(2) = 0.20, \quad F_{2,U}(2) = 0.05 \\ T_{3,U}(2) = 0.85, \quad I_{3,U}(2) = 0.40, \quad F_{3,U}(2) = 0.15 \end{aligned}$$

Step 2: Compute NIDF for Each Stakeholder

Using:

$$\mathrm{NIDF}_i(t) = \sqrt{\left(T_{i,U}(2) - T_{i,U}(1)\right)^2 + \left(F_{i,U}(2) - F_{i,U}(1)\right)^2}$$

$$\mathrm{NIDF}_1 = \sqrt{(-0.20)^2 + (0.15)^2} = \sqrt{0.04 + 0.0225} = \sqrt{0.0625} = 0.25$$

$$\mathrm{NIDF}_2 = \sqrt{(0.20)^2 + (-0.05)^2} = \sqrt{0.04 + 0.0025} = \sqrt{0.0425} \approx 0.206$$

$$\mathrm{NIDF}_3 = \sqrt{(0.05)^2 + (0.05)^2} = \sqrt{0.005 + 0.005} = \sqrt{0.01} = 0.1$$

$$\mathrm{NIDF}(2) = \frac{0.25 + 0.206 + 0.1}{3} \approx 0.185$$

Step 3: Compute EUAF

$$\mathrm{EUAF} = \frac{1}{3}(|0.30 - 0.10| + |0.20 - 0.25| + |0.40 - 0.15|) = \frac{1}{3}(0.20 + 0.05 + 0.25) = 0.167$$

Step 4: Compute SDI (Systemic Divergence Index)

Calculate means:

$$\bar{T}(2) = \frac{0.75 + 0.90 + 0.85}{3} = 0.833, \bar{F}(2) = \frac{0.20 + 0.05 + 0.15}{3} = 0.133$$

$$D_1 = (|0.75 - 0.833| + |0.20 - 0.133|) \cdot 0.30 = (0.083 + 0.067) \cdot 0.30 = 0.045$$

$$D_2 = (|0.90 - 0.833| + |0.05 - 0.133|) \cdot 0.20 = (0.067 + 0.083) \cdot 0.20 = 0.03$$

$$D_3 = (|0.85 - 0.833| + | 0.15 - 0.133|).40 = (0.017 + 0.017) \cdot 0.40 = 0.014$$

$$\text{SDI}(2) = \frac{0.045 + 0.03 + 0.014}{3} = 0.0297$$

Step 5: Compute SCWS*

Assume equal weights $\alpha = \beta = \gamma = 1$, and ignore CSFI and TEA for this example:

$$\text{SCWS}^*(2) = 0.185 + 0.167 + 0.0297 \approx 0.382$$

If the threshold $\tau = 0.35$, then SCWS* $> \tau$, indicating epistemic instability is emerging.

Step 6: Interpretation

Stakeholder 1, representing local performers, experiences a notable decline in perceived authenticity after the heritage element is adapted for tourism. This group also reports an increase in perceived distortion, indicating a sense of cultural disconnection or misrepresentation as the tradition shifts from its original context to a staged performance.

Stakeholder 2, comprised of international tourists, reports a significant increase in authenticity, suggesting a romanticized or surface-level perception of the tradition. This group largely overlooks signs of distortion, reflecting a lack of familiarity with the heritage's original form and purpose.

Stakeholder 3, consisting of cultural officials, demonstrates rising indeterminacy in their evaluations. This increase in uncertainty points to an internal conflict regarding how to frame or manage the heritage element under evolving political and commercial pressures.

4. Discussion and Theoretical Interpretation

The results confirm that the proposed neutrosophic epistemic framework effectively captures the internal instability of intangible heritage systems exposed to tourism dynamics. By modeling changes in authenticity, uncertainty, and falsity as evolving intervals, the framework goes beyond static assessment and provides a diagnostic tool for epistemic drift. The Neutrosophic Identity Drift Function (NIDF) quantifies the cultural displacement experienced by core stakeholders, while the Epistemic Uncertainty Accumulation Function (EUAF) reveals rising ambiguity within institutional interpretations. The Systemic Divergence Index (SDI) exposes how stakeholder perceptions fragment into incompatible narratives. Together, these components construct a real-time representation of cultural coherence.

From a theoretical perspective, this model represents a novel extension of interval neutrosophic logic into temporal and multistakeholder epistemic systems. Unlike traditional formulations that treat indeterminacy as residual or background noise, this approach models it as a dynamic, measurable signal of system health. The framework introduces original mathematical functions specific to neutrosophic instability, enabling proactive identification of collapse risk in heritage contexts. It not only preserves the logical independence of truth, indeterminacy, and falsity but operationalizes their fluctuation across time, making it applicable to both cultural research and policy intervention.

5. Conclusion

This paper introduces a dynamic extension to interval neutrosophic logic by formalizing time-sensitive functions that quantify epistemic drift, uncertainty escalation, and structural divergence in stakeholder-based systems. Unlike existing models that treat neutrosophic values as static descriptors, this framework redefines them as evolving intervals capable of signaling systemic instability.

The theoretical contribution lies in defining operational metrics such as drift, volatility, entropy, and collapse risk within the neutrosophic domain and integrating them into a

cohesive structure. These metrics preserve the logic's triadic independence while enabling application in environments where knowledge states are unstable, contested, or multi-actor. The result is a high-resolution, computation-ready model for monitoring cultural knowledge systems under pressure.

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