NSS
Neutrosophic Sets and Systems, Vol. 86, 2025
University of New Mexico

Analysis of New Development Paths for International Cultural Trade Based on Digitalization: A Neutrosophic Hyperreal Valuation Model (NHVM)

Yan Li*,Yu Cao
College of Humanity and Foreign Language, Xi'an University of Science and Technology, Xi'an, Shaanxi, 710054, China
*Corresponding author, E-mail: yy1111@xust.edu.cn

Abstract: The digitalization of global cultural trade introduces complexities in evaluating intangible cultural assets, such as digital art, NFTs, and virtual performances. These complexities arise due to subjective value perception, indeterminate ownership, and market volatility. In this paper, we propose a novel mathematical framework Neutrosophic Hyperreal Valuation Model (NHVM) based on nonstandard neutrosophic logic and hyperreal number theory. The model captures value shifts through infinitesimal changes, models uncertainty using neutrosophic sets, and defines partially ordered relationships between cultural entities via neutrosophic inequalities. We present a comprehensive set of definitions, equations, and practical valuation examples of cultural goods. This study provides new analytical tools for policymakers and cultural economists to understand and forecast digital cultural trade trends under indeterminacy and subjectivity.

Keywords: Digital cultural trade; neutrosophy; hyperreal valuation; NHVM; uncertainty modeling; international markets.

1. Introduction

Digital technology is changing how cultures connect and share across the world. It has created new ways to produce, share, and experience cultural products like virtual art, NFTs, live-streamed shows, and digital archives [1]. These digital cultural assets are different from traditional goods because their value is often intangible, subjective, and changes depending on context. This makes it hard to pin down their worth using standard economic models, which assume clear and stable values.

In digital cultural trade, things get even more complex. Cultural content moves across platforms from different countries, each with its own rules, politics, and economies. This blurs the lines between local and global, original and remixed [2]. For example, a digital artwork might be valued differently in various cultures, or its ownership might be unclear due to shared digital spaces. Traditional tools struggle to handle these ambiguities, conflicting interpretations, or uncertain pricing.

To tackle this, we propose a new way to value digital cultural trade using neutrosophic hyperreal logic. This approach, developed by Smarandache [3, 4], builds on classical logic but allows for partial truths, partial falsehoods, and indeterminate values that can be infinitesimally close to real numbers but not exactly defined. It's perfect for cultural trade, where subjective meanings and fluid identities are common. This study introduces a framework to better understand and analyze the value of digital cultural exchanges.

2. Literature Review

Recent research has explored how digital technology is reshaping cultural trade. Throsby [5] and UNESCO reports [6] show how digital cultural goods, like music or art created online, are becoming major exports. They also highlight how platforms, such as streaming services, are redefining creative work and blending cultural identities across borders.

On the technical side, researchers have used tools like fuzzy logic, probabilistic models, and game theory to study trade dynamics. Fuzzy logic, introduced by Zadeh [7], is good for capturing vague consumer preferences, like when someone "sort of" likes a digital artwork. Interval-valued models help when data is incomplete, providing ranges for uncertain values [8]. However, these methods struggle with situations where values are contradictory—like when a cultural product is both highly valued and controversial—or when values are infinitesimally close to a threshold but not exact.

The foundation of our study is nonstandard neutrosophic logic, pioneered by Smarandache [3, 4, 9]. This logic extends classical and fuzzy logic by using three components: Truth (T), Indeterminacy (I), and Falsehood (F). These can be subsets of a nonstandard unit interval, allowing for values that are slightly more or less than standard

numbers (called hyperreals) [4]. Smarandache introduced concepts like monads (sets of numbers infinitely close to a value) and neutrosophic hyperreals, which handle indeterminate or infinitesimal variations [9]. These tools are ideal for modeling the complex, subjective nature of cultural trade.

Despite its potential, neutrosophic hyperreal logic has rarely been applied to practical fields like international trade. Our research is the first to connect this logic to digital cultural trade, addressing a key gap in how we analyze and value these exchanges.

3. Methodology

We now develop a detailed, equation-rich framework for valuing digital cultural assets using neutrosophic hyperreal constructs.

3.1 Core Structure of NHVM

Each digital cultural good is assigned a **valuation triple**:

$$V_i = (T_i, I_i, F_i)$$

Where:

— T_i : Degree of perceived truth (market or cultural value)

— I_i : Degree of indeterminacy (uncertainty in value or ownership)

— F_i : Degree of perceived falsehood or irrelevance

Each of these can be:

— A real number: $T_i \in [0,1]$

— A hyperreal: $T_i \in R^*$ such that $T_i = 0.8 +$ or $F_i = -0.2$

— A neutrosophic hyperreal: e.g., $I_i = \{0.3, 0.3+\}$

3.2 Monads and Binads in Cultural Valuation

To reflect infinitesimal valuation changes, we define:

Right Monad (value infinitesimally greater than a):

$$a^+ = \{a + \varepsilon \mid \varepsilon \in R_+^*, \varepsilon \text{ is infinitesimal } \}$$

Left Monad (value infinitesimally less than a):

$$^{-}a = \{a - \varepsilon \mid \varepsilon \in R_{+}^{*}, \varepsilon \text{ is infinitesimal } \}$$

Binad (value infinitely close but not equal to a):

$$^{-}a^{+} = {}^{-}a \cup a^{+}$$

Example 1: NFT Artwork Value Approximation

Let an NFT's market value be estimated at 0.85 but perceived slightly higher in cultural forums:

$$T_{\text{NFT}} = 0.85^{+}, I_{\text{NFT}} = 0.1, F_{\text{NFT}} = 0.05$$

This means that the NFT holds a value greater than 0.85, but the exact amount is not known. The model captures this by allowing the value to fall just above 0.85, without needing to specify a precise number. This reflects how digital markets often work—where assets can seem more valuable based on hype or social attention, even if we can't assign an exact figure.

Part of the value is uncertain, around 10%, due to possible copyright concerns or unclear rules on the platform where the NFT is hosted. This indeterminacy reflects legal grey areas or questions about who really owns the content.

Additionally, 5% of the value is seen as false or irrelevant in some parts of the world. This might be because the style or subject of the NFT doesn't connect with certain audiences, or because it's considered unimportant outside specific cultural circles.

3.3 Neutrosophic Valuation Function

Define the valuation function:

$$V_i = \phi(T_i, I_i, F_i) = T_i - F_i - \lambda I_i$$

Where:

$\lambda \in [0,1]$ is the indeterminacy discount factor

This gives a net effective valuation, considering both uncertainty and negative perception.

Example 2: Apply to Previous NFT

$$V = 0.85^{+} - 0.05 - 0.1 \times 0.1 = 0.85^{+} - 0.05 - 0.01 = 0.79^{+}$$

The effective value remains higher than 0.79 due to the hyperreal 0.85^{+}.

3.4. Cultural Trade Inequality

Use neutrosophic inequality to compare two assets A and B :

$$A \geq_N B \Leftrightarrow T_A \geq T_B, I_A \leq I_B, F_A \leq F_B$$

This allows partial or indeterminate comparisons.

Example 3: Comparing Digital Opera (A) vs. Meme Pack (B)

$T_A = 0.9, I_A = 0.2, F_A = 0.1$
$T_B = 0.8, I_B = 0.3, F_B = 0.4$

Then

$A \geq_N B \Rightarrow$ Yes, since A has higher truth and lower indeterminacy/falsehood

3.5. Cultural Platform Value Aggregation

Let n digital goods $G_1, G_2, \ldots, G_n$ be traded on platform P.

Define the platform neutrosophic strength:

$$S_P = \frac{1}{n}\sum_{i=1}^{n} (T_i - F_i - \lambda I_i)$$

4. Results and Analysis

In this section, we apply the NHVM to real-like digital cultural assets traded across different digital platforms. We calculate the NHVM value for each asset and analyze what these values mean for international cultural trade in the digital age.

NHVM Equation

We use the NHVM formula to compute each asset's effective value:

$$V = T - F - \lambda \cdot I$$

In this formula, V represents the final or net value of the digital cultural asset after accounting for uncertainty and negative perception. It gives a more realistic picture of how the asset is valued overall.

The term T stands for the truth value. This shows how valuable or meaningful the asset is believed to be by its audience or the market. A higher T means the asset is seen as more culturally or economically important.

Next, I captures the level of uncertainty. This could come from unclear ownership, licensing problems, or lack of information about the asset. A higher I means there is more doubt or confusion about how the asset should be valued.

The value F refers to falsehood. This is the degree to which the asset is considered irrelevant, untrustworthy, or poorly received. A higher F lowers the overall value because it shows that some people or markets reject the asset.

Finally, the symbol λ is the penalty we apply to uncertainty. In this model, we fix it at 0.1. This means for every unit of doubt, the model subtracts 10% of that amount from the total value, helping us adjust for the effect of unknowns.

Example 1: Digital Opera on ArtStream

$T = 0.794, I = 0.078, F = 0.065, \lambda = 0.1$

$$V = 0.794 - 0.065 - (0.1 \cdot 0.078)$$
$$V = 0.794 - 0.065 - 0.0078$$
$$V = 0.7212$$

This shows the asset is moderately strong in market value after accounting for small uncertainty and falsehood.

Example 2: Digital Opera on MetaTrade

$$T = 0.938, I = 0.096, F = 0.025, \lambda = 0.1$$
$$V = 0.938 - 0.025 - (0.1 \cdot 0.096) = 0.938 - 0.025 - 0.0096 = 0.9034$$

This result is high, indicating the asset is very well accepted and carries minimal confusion or negative judgment.

Example 3: NFT Comic on MetaTrade

$$T = 0.739, I = 0.094, F = 0.097, \lambda = 0.1$$
$$V = 0.739 - 0.097 - (0.1 \cdot 0.094) = 0.739 - 0.097 - 0.0094 = 0.6326$$

This NFT has higher falsehood and indeterminacy, resulting in a noticeably lower valuation.

Example 4: Virtual Gallery Tour on CultureChain

Let's assume:

$$T = 0.900, I = 0.110, F = 0.030, \lambda = 0.1$$
$$V = 0.900 - 0.030 - (0.1 \cdot 0.110) = 0.900 - 0.030 - 0.011 = 0.859$$

This value is quite high due to strong cultural perception and minimal disinterest.

Cross-Platform Asset Comparison

We use neutrosophic inequality to compare value between platforms:

Let's compare the Digital Opera on MetaTrade and CultureChain:

On MetaTrade:

$V = 0.9034, I = 0.096, F = 0.025$

On CultureChain:

$$T = 0.883, I = 0.129, F = 0.016$$

$$V = 0.883 - 0.016 - (0.1 \cdot 0.129) = 0.883 - 0.016 - 0.0129 = 0.8541$$

Then

$$\text{MetaTrade Value} = 0.9034 > 0.8541 = \text{CultureChain Value}$$

So, MetaTrade is more favorable for this digital opera due to lower uncertainty and slightly lower falsehood.

Neutrosophic Strength of a Platform

We now define platform strength S_P as the average NHVM value of all assets it hosts:

$$S_P = \frac{1}{n}\sum_{i=1}^{n} (T_i - F_i - \lambda \cdot I_i)$$

On the MetaTrade platform, different cultural items show different levels of value. One of the top-rated pieces is a digital opera, which holds a strong position with a score of 0.9034. This suggests it is highly trusted and appreciated by its audience.

Another item available is an NFT comic, which has a value of 0.6326. This lower number points to mixed reactions, possibly due to limited appeal or uncertainty about its originality or importance.

The platform also features a virtual gallery tour with a value of 0.859. While not as high as the opera, it still shows solid support and relevance in the digital space.

These values help us see how each item performs individually and how they contribute to the overall cultural strength of the platform.

Then:

$$S_{\text{MetaTrade}} = \frac{0.9034 + 0.6326 + 0.859}{3} = \frac{2.395}{3} = 0.7983$$

MetaTrade has an average neutrosophic strength of 0.7983 , indicating a high general trust level in cultural value of its assets.

The NHVM model is helpful because it shows both clear and uncertain parts of a cultural asset's value. This is especially useful in digital trade, where different cultures may see the same content in very different ways, and those views can change over time.

It also allows us to capture very small changes in how people feel about something. For example, when a value is just a little more than 0.85 written as 0.85^{+} it shows a slight but meaningful shift in public interest or opinion. These tiny changes can make a big difference in fast-moving digital markets.

Instead of just counting how many items a platform offers, we can now measure the platform's strength based on how valuable and trustworthy its content is. This gives a deeper understanding of its real cultural impact.

When an item has a low score, it often means that people find it less relevant or there is a lot of confusion around it. A high level of falsehood, or even moderate uncertainty, combined with a strong penalty for doubt, can greatly reduce its overall value.

5. Discussion

The results from this study show that trading culture in a digital world needs more flexible tools than traditional economic models can offer. Digital cultural products, such as NFTs or online performances, often have unclear or shifting value. Their worth can depend on emotion, personal taste, or social trends. That makes it hard to measure them with fixed numbers or one-size-fits-all formulas.

Using the NHVM, we were able to model value in a way that accepts uncertainty. The model does not force a single answer. Instead, it allows value to be seen as partly true, partly false, and partly unknown. This matches how people often feel about cultural content—there's no single "right" answer, and value depends on who is looking.

Another key strength of the model is how it handles very small changes in how people see things. These small shifts might seem unimportant at first, but they can make a big

difference in digital markets. The NHVM uses hyperreal numbers to capture these subtle movements, which are common when content goes viral or trends shift quickly.

We also used the model to evaluate platforms. By looking at the average value of cultural items on a platform, we can get a better sense of its overall quality. This can help decision-makers understand which platforms are building trust and offering meaningful content, and which ones are not.

In short, the NHVM gives us a new way to think about digital culture. It accepts complexity instead of trying to simplify it. It shows how value can be flexible, personal, and even a little uncertain and that's exactly what makes it powerful in today's cultural trade environment.

7. Conclusion

In this study, we explored how digitalization is changing the way culture is traded across borders. We focused on the special challenges that come with valuing digital cultural products like online performances, NFTs, or virtual galleries where meaning and market value are often unclear or constantly changing. To deal with these challenges, we introduced a new model called the NHVM. This model helps describe value in a more realistic way by allowing us to include not only how valuable something is, but also how uncertain or controversial it might be. It recognizes that in the world of culture, value is rarely fixed or fully agreed upon. We applied the model to several digital cultural items across different platforms and found that small differences in perception, even those too small to measure exactly, can make a big impact on how these items are traded or received. The model also gave us a way to compare platforms more fairly not just based on popularity, but based on the trust and clarity of the content they offer.This approach gives artists, policymakers, and platform developers new models to understand the market. It also encourages a more thoughtful and fair system for evaluating cultural content, one that accepts complexity rather than trying to simplify everything into one number. General, this paper offers a new mathematical direction for thinking about

culture in a digital world. It blends logic and subjectivity in a way that matches how people actually experience and value culture online.

Acknowledgment

This work was supported by the Research on the capacity of cultural translation and international communication based on digitalization (Shaanxi Provincial Special Fund for Philosophy and Social Sciences under Grant No. 2024HZ0537).

References

[1] UNESCO, *Culture in the Digital Age: Re-Shaping the Global Cultural Trade*, UNESCO Publishing, 2020.

[2] Throsby, D., *The Economics of Cultural Policy*, Cambridge University Press, 2010.

[3] Smarandache, F., *Neutrosophy, Neutrosophic Probability, Set, and Logic*, ProQuest Information & Learning, Ann Arbor, Michigan, USA, 1998.

[4] Smarandache, F., *A Unifying Field in Logics: Neutrosophic Logic*, *Multiple Valued Logic / An International Journal*, Vol. 8, No. 3, pp. 385–438, 2002.

[5] Throsby, D., *Economics and Culture*, Cambridge University Press, 2001.

[6] UNESCO, *Global Report on Cultural Trade*, UNESCO Publishing, 2018.

[7] Zadeh, L. A., *Fuzzy Sets*, *Information and Control*, Vol. 8, No. 3, pp. 338–353, 1965.

[8] Moore, R. E., *Interval Analysis*, Prentice-Hall, 1966.

[9] Smarandache, F., *Advances of Standard and Nonstandard Neutrosophic Theories*, Pons Publishing House, Brussels, Belgium, 2019.

Received: Nov. 30, 2024. Accepted: May 31, 2025