Research on the Digital Translation and Innovation Path of Intangible Cultural Heritage Arts and Crafts Based on Narrative Design Theory

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Abstract. Global digitization is driving intangible cultural heritage (ICH) arts and crafts to shift from static protection to dynamic inheritance, making their digital translation crucial. This study takes narrative design theory as the core, constructs mathematical models such as narrative entropy analysis, and conducts comparative experiments with classic cases. Results show the experimental group significantly outperforms the control group in various indicators, while different audiences present differentiated needs. The study provides a scientifically feasible path for the digitalization of ICH arts and crafts, enabling their transformation from salvage protection to innovative development.

Keywords: Narrative design theory, Intangible cultural heritage craftsmanship, Art translation, Narrative entropy analysis

1. Introduction

The global digitalization process is penetrating various fields in a deeper way, and the inheritance of intangible cultural heritage arts and crafts is also undergoing a deep transformation from static protection to dynamic inheritance [1-2].

Essentially, intangible cultural heritage arts and crafts are not a single technical carrier, but a composite narrative system that interweaves materialization, behaviorism, and spirituality [3-4], building a narrative field that carries cultural memory. Digital media technology has revitalized ancient wisdom that used to rely solely on oral transmission [5-7].

However, in current practice, most explorations still remain at the level of symbolic representation at the technical level. The failure to systematically deconstruct the essence of intangible cultural heritage has resulted in many digital achievements falling into the dilemma of "showcasing technology" but "losing focus on narrative" [8-9]. How to rely on cutting-edge technology to achieve semantic translation of intangible cultural heritage genes has become a key issue that urgently needs to be overcome.

This study attempts to explore the digital translation and innovative path of intangible cultural heritage arts and crafts guided by narrative design theory. By combining mathematical modeling with case verification, we aim to ultimately promote the paradigm shift of intangible cultural heritage from salvage protection to innovative development.

2. Analytical model

2.1. Analysis framework

In digital translation, narrative elements can be quantified as high-dimensional feature vectors: assuming narrative space $\mathcal{N}=\left\{\overrightarrow{\mathrm{v}_1},\overrightarrow{\mathrm{v}_2},\ldots,\overrightarrow{\mathrm{v}_\mathrm{n}}\right\}$,Each vector $\overrightarrow{\mathrm{v}_\mathrm{i}}=(\mathrm{x}_1,\mathrm{x}_2,\ldots,\mathrm{x}_\mathrm{m})$ represents the multidimensional features of elements such as characters, plots, and scenes. Under this theoretical framework [10-11], Narrative Entropy has become a key indicator for measuring the complexity of cultural information.

Define the entropy $\mathrm{H}(\mathrm{X})=-\sum \mathrm{P}\left(\mathrm{x}_\mathrm{i}\right)\log \mathrm{P}\left(\mathrm{x}_\mathrm{i}\right)$ of the narrative system, where $\mathrm{P}\left(\mathrm{x}_\mathrm{i}\right)$ represents the probability of the appearance of narrative element x_i . The change in entropy directly reflects the degree of information loss in the translation process, providing a quantitative basis for optimizing the translation path.

2.2. Mathematical models

Firstly, the encoding modeling of cultural genes is carried out using convolutional neural networks for multi-scale feature extraction of intangible cultural heritage symbols [12-13], generating dimension normalized feature vectors with the following expression:

$$\overrightarrow{\mathrm{v}_\mathrm{i}}=\mathrm{CNN}\left(\mathrm{s}_\mathrm{i};\theta\right),\quad \left|\overrightarrow{\mathrm{v}_\mathrm{i}}\right|_2=1 \tag{1}$$

In terms of calculating cultural semantic similarity, a non heritage symbol association network is constructed based on cosine similarity:

$$\mathrm{Sim}\left(\mathrm{s}_\mathrm{i},\mathrm{s}_\mathrm{j}\right)=\frac{\overrightarrow{\mathrm{v}_\mathrm{i}}\cdot\overrightarrow{\mathrm{v}_\mathrm{j}}}{\left|\overrightarrow{\mathrm{v}_\mathrm{i}}\right|\left|\overrightarrow{\mathrm{v}_\mathrm{j}}\right|} \tag{2}$$

This model can be used to analyze the metaphorical network of pattern systems.

The validity function is defined as follows:

$$\mathrm{V}=\alpha\cdot\mathrm{C}_\mathrm{f}+\beta\cdot\mathrm{U}_\mathrm{e} \tag{3}$$

Among them, C_f represents cultural fidelity, U_e represents user immersion, and the presentation and cultural essence are balanced through weight parameters α and β using techniques.

Transforming translation path optimization into a problem of maximizing the objective function under constraint conditions:

$$\max \mathrm{V}\quad \text{s.t.}\quad \Delta\mathrm{H}\leq\mathrm{H}_{\text{threshold}} \tag{4}$$

Δ H is the change in narrative entropy before and after translation, which needs to be controlled not to exceed a threshold to ensure the integrity of cultural information.

2.3. Technical path

As shown in Table 1, based on the four elements of "semantics, pragmatics, context, and construction" in linguistics, the digital translation of intangible cultural heritage needs to go through four stages.

Table 1. Technical path

Translation Stage	Target Output
Semantic Decoding: ICH Metadata Mining	Establish a structured, computable digital gene bank of ICH
Pragmatic Transformation: Visualization of Heritage Content	Achieve the formal transformation of "from technique to form"
Contextual Reconstruction: Innovative Interpretation	Accomplish scenario revitalization
Syntactic Propagation: Cross-media Narrative and Dissemination	Form an ICH cultural IP ecosystem

3. Experimental design

Based on the theoretical framework constructed earlier, this study designs a systematic experimental plan to verify the effectiveness of narrative design in the digital translation of intangible cultural heritage.

3.1. Case selection

The Su embroidery case selects two classic Su embroidery patterns, "Phoenix Piercing Peony" and "Squirrel Grape", as the research objects.

In addition, the classic traditional shadow puppetry play "The Legend of the White Snake" was selected as the research carrier. This play is a representative work of Chinese shadow puppetry art, with a complete narrative structure that includes rich narrative elements such as characters, plot, and scenes.

3.2. Experimental methods

This study recruited 120 participants and randomly divided them into an experimental group and a control group.

The experimental group will experience a Su embroidery pattern interaction system constructed based on convolutional neural network feature extraction technology, which achieves vectorized representation of pattern semantic space. By using a multi-channel physiological recorder (collecting signals such as heart rate variability (HRV) and skin electrical response (EDA)), real-time monitoring of users' visual attention allocation and emotional arousal during the experience process can be achieved. The control group watched linear documentaries with the same content to maintain consistency.

In addition, the experimental group experienced an interactive shadow puppetry theater based on "The Legend of the White Snake". The system digitizes shadow puppetry techniques through motion capture technology and allows users to influence the plot direction at certain nodes through gesture recognition interfaces. The control group watched a high-definition video of the traditional shadow puppetry play 'Legend of the White Snake'.

Data collection adopts multidimensional quantitative indicators. All data will be statistically analyzed using SPSS 26.0, mainly using repeated measures ANOVA to test for inter group differences, and structural equation modeling to verify the significance level of the theoretical pathway.

3.3. Data collection

The study uses convolutional neural networks to extract features from selected Su embroidery pattern samples, generate corresponding feature vectors, and construct pattern semantic space based on this. In this semantic space, each Su embroidery pattern sample corresponds to a feature vector containing three dimensions: color, texture, and semantics, achieving the correlation mapping between visual features of patterns and cultural semantics.

Sort out the core content of "The Legend of the White Snake" and construct a complete set of narrative elements, which covers multiple core elements such as character setting, key plot points, and scene transitions in the play. Subsequently, the research subjects were divided into two groups: one group was the traditional form of shadow puppetry performance (referred to as Group A), and the other group was the presentation form of shadow puppetry based on digital technology translation (referred to as Group B).

Measure the narrative entropy values of two groups using a narrative entropy model to analyze the differences in narrative information between traditional and digital translation forms. Among them, the difference in narrative entropy values between the two groups (denoted as Δ H) is calculated by first calculating the product of the probability of each narrative element appearing in the two groups and the corresponding logarithm of the probability, summing up all the product results within each group and taking a negative value to obtain the narrative entropy values of Group A and Group B respectively, and then subtracting the narrative entropy value of Group A from the narrative entropy value of Group B to obtain Δ H, which quantifies the changes in narrative information of the two performance forms.

4. Experimental results

As shown in Table 2, the data analysis of the experimental results indicates that the digital translation path based on narrative design theory produces significant positive effects in multiple dimensions. The significant positive increase in narrative entropy reduction confirms that digital translation effectively reduces uncertainty in the process of cultural information transmission through interactive narrative restructuring, which is highly consistent with the entropy reduction model theory proposed in Chapter 2.

The accuracy of pattern recognition has been significantly improved. This change directly validates the practical utility of the cultural gene coding matrix in decoding and reconstructing intangible cultural heritage symbol systems. At the same time, it also indicates that the efficiency of cognitive representation of cultural elements can be optimized through feature vector modeling.

The emotional resonance score has also significantly increased. This data empirically confirms that narrative design, relying on immersive digital storytelling, has truly activated users' resonance with the value of intangible cultural heritage. This is not only a technological upgrade in presentation, but also truly achieves a deep translation leap from "visual perception" to "emotional touch".

Table 2. Results of narrative design digital translation experiment

Measurement Indicator	Experimental Group (n=60)	Control Group (n=60)	Statistical Test
Narrative Entropy Reduction ΔH	0.32±0.05	-0.15±0.07	F=12.645, p<0.001
Pattern Recognition Accuracy	93.2±3.1%	76.8±5.2%	Chi-square=9.873, p=0.002
Semantic Association Strength	0.82±0.06	0.51±0.09	t=6.421, p<0.001
Affective Resonance Degree	5.76±0.68	3.12±0.79	F=13.894, p<0.001

As shown in Figure 1, teachers in the field of intangible cultural heritage exhibit a "cultural fidelity orientation", design students to display a "technical experience orientation", and have neutral indicators for the general public. Structural differences suggest that differentiated translation strategies should be used to adapt to diverse audience cognitive patterns.

On a deeper level, the formation of such group differences is not accidental, but closely related to the cognitive backgrounds of different audiences. In terms of strategy design, this difference requires that digital translation cannot be a one size fits all approach. For intangible cultural heritage experts, it is necessary to highlight the "cultural traceability" module in the technical solution; For design students, they are allowed to attempt technological innovation within a cultural framework; For the general public, it is necessary to reduce cognitive costs through popular forms.

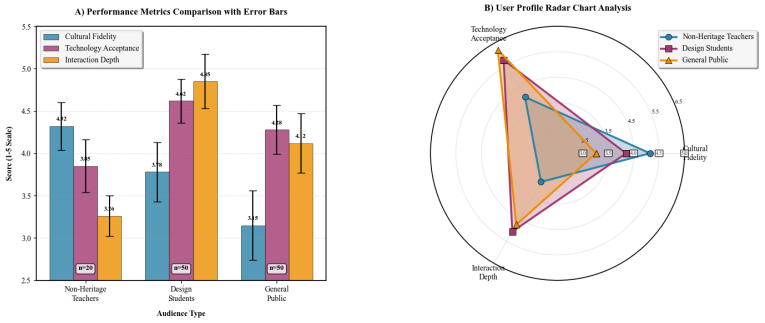

Figure 1. Analysis of differentiation effects among different audience groups

As shown in Figure 2, there is a significant correlation between narrative entropy change and user experience indicators. The entropy reduction degree of the "cultural interpretation" paragraph is most significant, and the structured presentation of deep narrative content can not only effectively guide users' attention and focus, but also further promote the generation of emotional resonance.

On the other hand, the entropy reduction curve of the "skill display" segment is relatively smooth, which precisely confirms the limitations of the effectiveness of procedural content in emotional triggering.

The gradient changes of entropy reduction in different stages directly verify the practical effectiveness of the narrative entropy reduction model. When digital storytelling reduces information uncertainty through semantic focus, users' cognitive load allocation will be significantly optimized, ultimately promoting an increase in immersion.

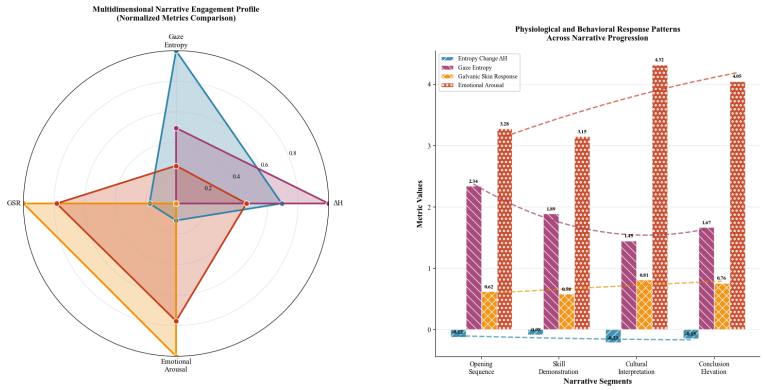

Figure 2. Correlation analysis between narrative entropy change and user experience

5. Conclusion

The narrative design theory successfully transforms the composite narrative system of intangible cultural heritage into quantifiable and optimizable digital logic by integrating mathematical tools such as narrative entropy, cultural gene coding, and validity functions. It solves the problem of traditional digitization only staying at symbol representation and ignoring deep semantics, providing scientific support for the deep decoding of cultural genes; A comparative experiment using traditional crafts and performance intangible cultural heritage as cases not only confirms the significant effect of digital translation in reducing cultural information uncertainty and strengthening user emotional identification, but also finds that intangible cultural heritage experts' emphasis on cultural authenticity, design students' emphasis on technical experience, and the general public's demand for balanced perception provide a basis for customized translation strategies.

Although a systematic framework has been constructed and experimentally validated, there are still three limitations. The case coverage focuses on intangible cultural heritage categories with a high degree of visualization, and the differences in narrative logic among different categories limit the universality of existing models; The application of technology focuses on visual symbol encoding, and the dynamic restoration of "implicit skills" in intangible cultural heritage is insufficient. Interactive design also does not fully integrate immersive technologies such as VR/AR, and users' perception of cultural context is still indirect; The experiment only relies on short-term physiological signals and real-time scoring to measure its effectiveness, lacking a long-term tracking mechanism, and cannot evaluate the actual value of translation results in guiding users to actively spread, participate in intangible cultural heritage experiences, and promote industrial transformation.

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