# Bridging Through Multisensory Experiences: The Inheritance and Innovation of Grand Canal Intangible Cultural Heritage in Cultural and Creative Products

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**Abstract.** To advance the preservation and promotion of the Grand Canal's intangible cultural heritage (ICH), this study introduces a multisensory design strategy and validates its practical application. Through a comprehensive literature review, the necessity and feasibility of integrating multisensory design into ICH were substantiated. A structured design framework was developed, encompassing input analysis, data processing, and output evaluation. Six representative traditional operas and their associated musical instruments from the Grand Canal region were selected as case studies. Leveraging sound visualization technology and Arduino components, a prototype of a cultural and creative product was created, integrating visual, auditory, and tactile sensory experiences. This product not only enhances user engagement and cultural identification but also, through user-customized design and 3D printing technology, achieves innovative approaches to personalized cultural experiences and product customization. The findings demonstrate that multisensory design holds significant potential for ICH inheritance, offering novel insights and methodologies for the living heritage transmission of the Grand Canal and other cultural heritages.

**Keywords:** Multisensory Design；Grand Canal Cultural Landscape；Multimodal Sensory Integration; Strategic Design Framework.

## 1. Introduction

The Grand Canal, a vital living cultural heritage of China, served as a crucial artery for north-south transportation in ancient times, fostering a wealth of intangible cultural heritage (ICH). Notably, it facilitated the integration of northern and southern operas, giving rise to diverse local opera genres along its route. However, many of these distinctive local opera genres are not well-known nationwide and are in urgent need of protection and inheritance. Multisensory design, an emerging field, has seen limited application in the context of the Grand Canal. This study focuses on applying multisensory design to the ICH of the Grand Canal, proposing a novel design strategy framework and implementing it in the context of the canal's opera heritage.

## 2. The Diverse Values of the Grand Canal's Intangible Cultural Heritage (ICH)

The culture of the Grand Canal, rooted in the Canal itself, is characterized by its “vitality” and “integration,” organically connecting diverse cultural elements from regions such as Yan-Zhao, Qi-Lu, Central Plains, and Jiangnan. It serves as a crucial bond for the dissemination and innovation of Chinese civilization. Along the Canal, a rich variety of artistic forms have flourished, including Shandong Bangzi Opera, Suzhou Pingtan, and traditional crafts like Tianjin’s “Clay Figurine Zhang” and Yangliuqing Woodblock New Year paintings, all showcasing unique artistic charm. The regions along the Grand Canal are not only vital for economic development but also the core zone for the inheritance of Chinese culture. By enhancing cultural inheritance and exchange functions, local economic and cultural development has been promoted. In recent years, the Chinese government has actively organized international cultural exchange activities, such as the Grand Canal Cultural Festival, which have deepened global understanding of traditional Chinese culture and fostered mutual understanding and friendly exchanges among different civilizations.

## 3. The Necessity of Applying Multisensory Design to the Grand Canal's Intangible Cultural Heritage (ICH)

The Grand Canal, a treasure of ancient Chinese civilization, is not only a waterway flowing with a millennium of history but also a cultural corridor rich with intangible cultural heritage (ICH). Applying multisensory design to the protection and dissemination of the Grand Canal's ICH demonstrates respect for and continuation of traditional culture while integrating and innovating with modern civilization. It revitalizes the Grand Canal's ICH in a novel manner, breaking through the limitations of traditional display methods to present the heritage to the public in a more vivid and intuitive way. This approach enhances the cultural value and social impact of the Grand Canal's ICH, making multisensory design not only a significant research focus but also an essential pathway for the sustainable development of intangible cultural heritage.

## 4. Current Status of Grand Canal ICH Design and Multisensory Design

Currently, the design of cultural and creative products related to the intangible cultural heritage (ICH) of the Grand Canal is primarily concentrated in the visual and auditory domains. For instance, Zhao Yun et al. [1]focused on the culture of the Grand Canal in Changzhou, integrating traditional patchwork art to design cultural and creative graphic patterns. Yang Yang [2]further explored the fusion of canal ICH with digital technology, using Qinhuai lanterns as a case study to investigate the application of AR technology in the digital design and display of skill-based ICH. In addition to visual design, a few scholars have attempted immersive experience designs that combine visual and auditory elements. Xu Wenxue et al.[3]utilized various new media technologies to enhance the depth of interaction between the Grand Canal's ICH in Jiangsu section and its audience through immersive animation design. While visual and audio-visual integrated designs have played a role in disseminating the Grand Canal's ICH, the lack of exploration in multisensory design has led to homogenization of cultural and creative products. This, in turn, diminishes their effectiveness in sustaining the "living" inheritance and effective dissemination of ICH. Liu Linlin et al. also pointed out that although Grand Canal-related cultural and tourism products are not uncommon in the market, the overall quality of design needs improvement, and the situation is not optimistic[4].

Multisensory design research, both domestically and internationally, currently focuses mainly on the integration of multiple senses, such as vision, hearing, and touch, through interactive design. Few studies have explored cross-sensory design, with most of these focusing on sound visualization. In China, Professor Xu Baiming [5] conducted research on "phonetics" in sound visualization, analyzing how different imaging media, based on their physical properties, can enhance the expression of various sound emotions. In the context of Dong ethnic song product design , immersive digital imaging technology was applied to create vivid soundscapes, emphasizing the visualization of sound in graphic design[6].

Internationally, Smuts, Lyn [7]argued that since the Renaissance, Western culture has been dominated by vision, which is a distancing medium. They suggested that sound should interact with vision to create a greater impact. Llorca-Bofí [8]analyzed the framework of sound data, combining open-source auditory tools like Virtual Acoustics with 3D visualization to achieve auditory and visual settings for urban scenes.

Overall, current research in the field of multisensory design mostly remains at the level of sensory integration or the establishment of digital analysis models, with limited in-depth exploration of cross-sensory design.

In summary, most ICH cultural and creative designers focus on visual design, neglecting multisensory design. In the field of multisensory design, most scholars choose to conduct data analysis and evaluation through sound visualization, with few exploring the integration of sound visualization with product design. Therefore, the research area of combining ICH cultural and creative products with sound visualization is relatively underexplored, highlighting the importance of further exploration in this direction.

# 5. Research Content

## 5.1 Research Method

Within Within the broad scope of multisensory design, synesthesia, as a strategy to deeply explore and stimulate human sensory experiences, holds significant importance for the design practice of intangible cultural heritage (ICH). Synesthesia reveals the interdependent yet complementary relationships between senses, emphasizing that the effect of multisensory integration far exceeds the simple summation of individual sensory stimuli. In the inheritance and innovative design of ICH, synesthetic methods can more comprehensively awaken the audience's emotional memory and cultural identity, thereby enhancing the design's emotional appeal and transmissibility. Merleau-Ponty's concept of "synesthetic experience"[9]provides a crucial theoretical foundation for ICH design, as he emphasized that constructing a comprehensive synesthetic perception environment is essential for achieving immersive cultural experiences. This perspective inspires designers to focus on the integration and interaction between senses, guiding experiencers into a holistic and multi-layered perceptual state through delicate combinations of sensory stimuli.

Furthermore, the sensory compensation mechanism in synesthesia not only promotes collaboration between different sensory modes but also cleverly compensates for the limitations of certain senses. For instance, visually impaired individuals can access richer information through hearing and touch. The application of this mechanism significantly enriches the connotation of ICH sensory design, making it a key factor in simulating and transcending real environments to create unique cultural experiences. Therefore, in ICH design, deeply exploring the potential of synesthesia and integrating sensory compensation principles is an effective approach to building profound sensory experiences, promoting the inheritance and innovation of ICH.

## 5.2 Design Strategy

When constructing the design strategy framework for applying multisensory design to the field of intangible cultural heritage (ICH) culture (Figure 1), the first step is to conduct an input analysis. This involves collecting and identifying ICH-related information through the five senses—vision, hearing, smell, taste, and touch. It also includes in-depth research into traditional skills and art forms of ICH, such as traditional cuisine, architecture, opera music, folk culture, art design, digital media, and cultural tourism. Additionally, user needs and preferences regarding ICH culture are investigated to provide direction for the design.

In the data processing phase, the information from the five senses is integrated through synesthesia to form a multisensory experience. The characteristics of ICH culture are extracted and matched with the results of synesthetic integration to ensure cultural relevance and consistency in sensory experience. User needs and preferences are also considered to better meet their expectations in the design process.

In the output evaluation stage, a multisensory design framework for ICH culture is constructed based on the results of input analysis and data processing. Practical design implementations are carried out by integrating ICH elements and multisensory experiences into specific designs. User feedback is collected through user experience testing to assess the effectiveness and user satisfaction of the design. The social impact of the design is also evaluated, including aspects of cultural inheritance, educational significance, and social acceptance. Finally, the design plan is continuously optimized and upgraded based on user feedback and social impact assessments.

This design strategy framework provides a complete structure from theoretical research to practical application and effect evaluation. It aims to enhance the inheritance and experience of ICH culture through multisensory design. This not only helps protect and disseminate ICH culture but also improves user cultural experiences and promotes the modern transformation and innovation of ICH culture.

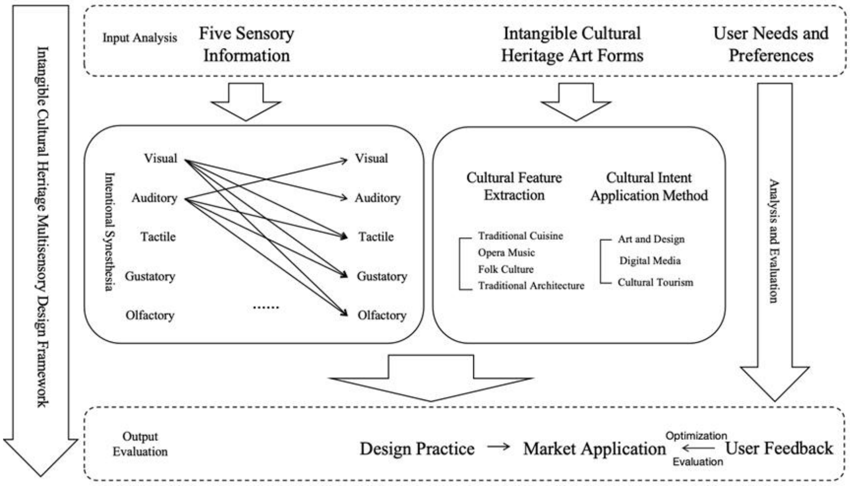


Fig. 1 Intangible Cultural Heritage Multisensory Design Framework

# 6. Multisensory Design Practice Based on the Intangible Cultural Heritage (ICH) of the Grand Canal

## 6.1 Design Orientation

The Grand Canal, a vital living cultural heritage site in China, has nurtured rich intangible cultural heritage (ICH), particularly through the integration of northern and southern opera traditions. Cities like Suzhou, Wuxi, and Yangzhou host diverse opera genres, yet many remain underrecognized and require urgent protection and inheritance.

With technological advancements, consumer demand for cultural products has surpassed functionality and aesthetics. This study integrates multisensory design with the Grand Canal's ICH opera culture, offering users novel cultural experiences and fostering deeper engagement, thus providing a sustainable development pathway for these heritages.Through innovative design, this study aims to enhance interactivity and user experience, better preserve and disseminate the Grand Canal's ICH, and encourage broader participation in safeguarding this cultural treasure of humanity.

## 6.2 Practice Scheme

### 6.2.1 Element Extraction

Among the numerous origins of intangible cultural heritage (ICH) operas along the Grand Canal, six traditional opera birthplaces representing the cultures of the Beijing-Tianjin area, Yan-Zhao region, Central Plains, and Wu-Yue region were selected. Representative musical instruments from these opera cultures were extracted as the prototype forms for the products. By programming and generating audio-visual synesthetic patterns, these instruments were combined with their respective characteristics to establish models.

Beijing Opera, a quintessential genre of Beijing, plays a pivotal role in the ICH culture of the Grand Canal. The erhu, selected as its symbolic instrument, represents both Beijing Opera and the local folk culture of Beijing. In form design, an innovative approach was employed to enhance the erhu's audio-visual synesthetic experience. Using Processing software, dynamic linear curves simulating the vibration patterns of the erhu strings during performance were programmed and integrated with the strings, creating a visually dynamic effect. This design preserves the erhu's traditional form while conveying musical rhythm and emotion through visual elements, allowing users to intuitively perceive the flow and tension of the music. This achieves a harmonious unity of sound and vision, enhancing the product's cultural expressiveness and sensory appeal.

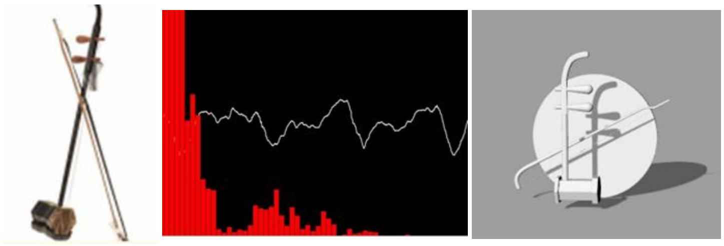

Fig. 2 The Erhu and Its Synesthetic Patterns and Models

Shandong, a city along the Grand Canal, is home to the lesser-known intangible cultural heritage (ICH) of Shandong Bangzi Opera, also referred to as "Lu Bang." In 2006, it was included in the first batch of the National List of Intangible Cultural Heritage. Known for its high-pitched and passionate music, Shandong Bangzi features vigorous and brisk vocal melodies, excelling in portraying intense emotional conflicts and dramatic tension. The musical ensemble typically comprises string, wind, and percussion instruments. In our synesthetic design, we selected the representative instrument, the clapper (bangzi), and integrated its form with the waveform of an audio bar chart, designing the clapper in a linear format.

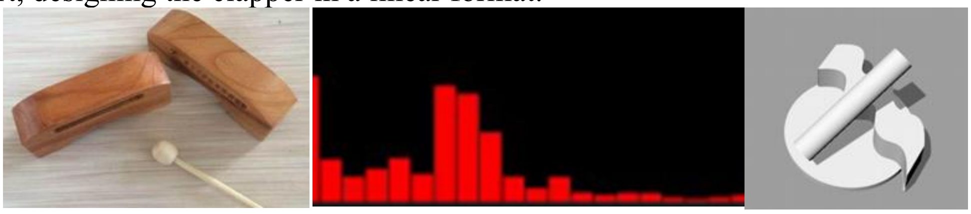

Fig. 3 The Bangzi and Its Synesthetic Patterns and Models

In Hebei, we selected the lesser-known intangible cultural heritage (ICH) of Hebei Diao, which blends local dialects and folk songs into a distinctive style. Representative pieces such as "Duìhuā" and "Màicài" from Jidong and "Fàngfēngzheng" from Jinan showcase strong regional characteristics. The suona horn, chosen as the representative instrument, further highlights these features. For its visual representation, concentric circular patterns were generated using an algorithm designed in Processing, simulating the sound diffusion effect during suona performance and aligning with its top-down perspective. This design visually conveys the dynamic diffusion of sound waves, as if the sound visibly emanates from the instrument, deepening the audience's perception of suona music and transforming each viewing into an audio-visual feast.

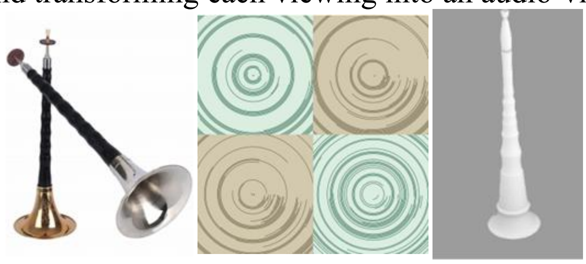

Fig. 4 The Suona and Its Synesthetic Patterns and Models

In Yangzhou, we focused on Kunqu Opera, a gem of China's intangible cultural heritage, which integrates the Wu dialect, traditional poetry, and graceful dance movements to create classic plays like "The Peony Pavilion" and "The Palace of Eternal Life," reflecting the unique charm of Jiangnan water towns. The sheng, chosen as one of Kunqu's accompanying instruments, embodies this regional character. In its design, annular sound wave patterns generated through a Processing-based algorithm were applied to the sheng's pipes from a top-down perspective, visually conveying a fluid sense of sound as if the music flows out in a visualized form. This design deepens the audience's emotional resonance with the sheng music, transforming each performance into an unforgettable audio-visual experience.

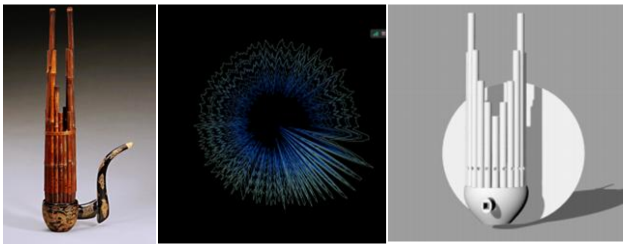

Fig. 5 The Sheng and Its Synesthetic Patterns and Models

Suzhou Pingtan, a quintessential form of traditional Chinese storytelling and music, holds a prominent place within the intangible cultural heritage (ICH) of the Grand Canal. We selected the yangqin as the representative instrument for this art form, deeply rooted in Suzhou's cultural soil and embodying the city's unique elegance and charm. In terms of visual creativity, we explored the yangqin's aesthetic features, extracting its outline and integrating it into the product design to retain its classic image while infusing modern simplicity. Using Processing software, we digitally processed audio segments of Suzhou Pingtan, abstracting them into linear visual elements and integrating these with the yangqin's string design. This approach respects the yangqin's traditional beauty while harmoniously blending sound and vision through innovative visual expression, enhancing the product's cultural depth and enriching the user experience, allowing users to feel the seamless integration of tradition and modernity.

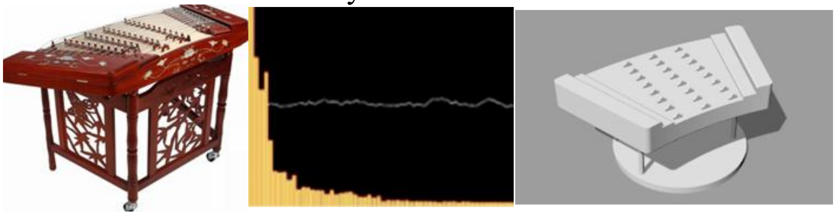

Fig. 6 The Yangqin and Its Synesthetic Patterns and Models

Shaoxing Opera (Yueju), an artistic treasure of Hangzhou, holds a significant place in China's intangible cultural heritage. We selected the pipa as its representative instrument, as it not only accompanies Shaoxing Opera but also reflects Hangzhou's delicate cultural essence. In creative presentation, we transformed the pipa's audio fluctuations into visualized curves, simulating musical fluidity, and integrated them with the pipa's strings through algorithmic design. This audio-visual approach enriches the pipa's contemporary expression and deepens the audience's perception of the music. As the curves undulate with the rhythm, viewers seem to hear notes leaping from the strings, creating a harmonious linkage between sound and form. This design turns the product into an audio-visual feast, allowing viewers to appreciate the pipa's charm while experiencing Hangzhou's cultural and artistic allure.

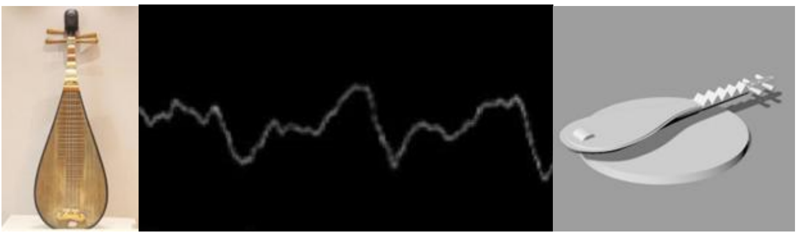

Fig. 7 The Pipa and Its Synesthetic Patterns and Models

#### 6.2.2 Program Design

This design integrates the elements of intangible cultural heritage (ICH) opera instruments with multisensory design, aiming to promote the innovative development of cultural and creative products along the Grand Canal. The innovative approach of synesthesia applies the results of sound visualization to user-customized designs. In the shape design section, audio clips of on-site experiences with ICH instruments are first imported into the Processing program (see Figure 8) for synesthetic processing between auditory and visual elements. Subsequently, the audio data is transformed into two-dimensional patterns through dimensional conversion, which are then adapted for application to the three-dimensional forms of the ICH instruments (see Figure 9).

In the program implementation section, Arduino components are integrated into the base module and the instrument module (see Figure 10). Users can place the instrument modules, representing different regional opera styles, onto the base module according to their geographical locations along the Grand Canal (see Figure 11). This action triggers the playback of classic excerpts from the corresponding opera. By interacting with the product, users achieve a synesthetic experience involving sight, hearing, and touch, enriching their sensory engagement.

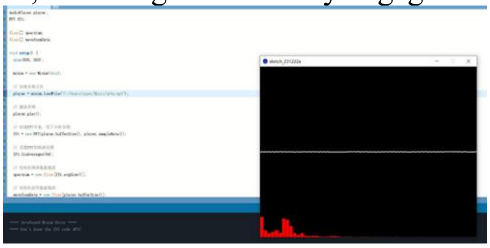

Fig.8

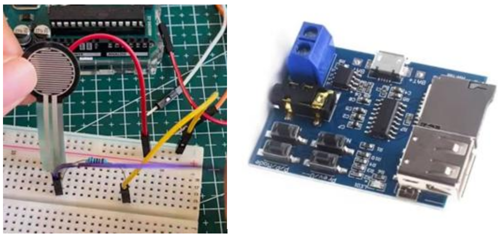

Fig. 10

Fig. 9

Fig. 11

### 6.3 Analysis of Innovative Aspects in Design Practice

6.3.1 Mechanism Innovation

The essence of mechanism innovation lies in seamlessly merging the Grand Canal ' s cultural richness with sensory experiences to establish a novel interactive paradigm. Leveraging sound visualization technology, historical sounds of the Grand Canal and traditional music from its riparian areas are transformed into intuitive visual representations. Utilizing programming tools like Processing, visitors can engage with these " canal sounds " in real-time within scenic zones. Through touchscreens, mobile devices, or other sensing interfaces, users manipulate sounds and images, fostering a deeper exploration of the Grand Canal ' s cultural heritage. This approach not only boosts visitor engagement but also renders abstract auditory information more tangible and accessible.

6.3.2 Path Innovation

Path innovation is manifested through integrated multi-sensory design, combining sound visualization with tailored cultural and creative souvenir toys. By merging visual, auditory, and tactile experiences, a more immersive and interactive user experience is achieved. Products are customized based on user interactions and sound visualization data, enhancing purchasing appeal and broadening audience reach.

6.3.3 Model Innovation: Personalized Cultural Experience and Product Customization

Beyond real-time interaction, visitors can employ 3D printing technology to create personalized musical toys post-experience. These toys consist of a base and modular components, which users collect during their journey along the Grand Canal. This method, more engaging than traditional stamp or badge collections, integrates sound visualization into cultural and creative toys, transforming auditory data into three-dimensional designs. These toys not only serve as travel mementos but also as effective tools for disseminating the Grand Canal’s cultural legacy.

## 7. Conclusion

This paper constructs a multisensory design framework for the inheritance and promotion of the Grand Canal’s intangible cultural heritage (ICH), proposing design strategies from input analysis to output evaluation through theoretical and practical research. Six representative operas and their instruments along the Grand Canal were selected for the practical section. Using sound visualization technology and Arduino components, a prototype integrating visual, auditory, and tactile synesthetic experiences was developed. User-customized design and 3D printing enhanced the product’s interactivity and appeal, offering new approaches for ICH inheritance. Practice shows that multisensory design significantly improves user experience and cultural identification, opening new pathways for ICH sustainability. User feedback also provided data support for optimizing product design and service models. This research contributes innovative solutions for the Grand Canal’s ICH protection and dissemination, while offering references for the living inheritance of other cultural heritages.

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