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# Research on the visualization of information of Chinese traditional music with human-computer interaction from the perspective of metaverse

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## ABSTRACT

In the metaverse environment, establish an immersive human-computer interaction system for Chinese traditional music based on virtual reality technology. Design the system's functionality according to the Y model, and construct a four-layered system architecture. Collect high-quality instructional audio and utilize polygon modeling technology to create contextualized scenes of Chinese traditional music, as well as high-fidelity models of characters and instruments. Implement motion capture through inertial sensor technology for performance action data mapping. Utilize a metaverse engine platform to realize interactive functions and conduct performance optimization. The system is capable of eliciting learners' intrinsic experiences, enabling interactive self-directed learning and creative exploration of Chinese traditional music performance, demonstrating significant practical value.

***Keywords:*** metaverse; Chinese traditional music; human-computer interaction

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## 1. Introduction

In recent years, the field of music performance is on the brink of a new revolution driven by the application of virtual technologies. Since the advent of the "Metaverse year" in 2021, an increasing number of extended reality (XR) technologies, augmented reality (AR) technologies, and the Metaverse have been intersecting, leading to a rise in virtual performances on various platforms[1]. As the global live performance industry faces challenges with declining trends and prolonged closures of performance venues, traditional face-to-face activities are transitioning predominantly to non-face-to-face performance formats. The way people interact online is becoming more uniform, and the mode of music appreciation is evolving from being centralized in concert halls and theaters to online modes that prioritize interaction, communication, and audience participation.

Consequently, the era of creating virtual spaces from the originally face-to-face real spaces has begun, where avatars interact with each other. Online virtual music performances are transforming into the world of the Metaverse, with virtual technologies gradually merging seamlessly with art. The COVID-19 pandemic has accelerated the arrival of a global era of digital economic transformation, and the Fourth Industrial Revolution has led to the rapid advancement of network technologies, heralding the

comprehensive arrival of the 5G era. Artificial intelligence, from its conceptualization in 1956 to the development of AI industrial intelligence technology in the 21st century, has continuously propelled the boundaries of the application areas of performing arts alongside the development of digital technologies. The convergence between the physical space used in performances and technological genres has become particularly prominent. People have become accustomed to and accepted "Untact" (non-contact, non-face-to-face) online performance art forms.

The presentation forms of music performance art are not only confined to physical spaces such as concert halls, theaters, outdoor venues, etc., but also extend into media spaces, including television, recorded videos, images, digital platforms, and online media network platforms. With the development and integration of technology, an increasing number of music performance forms are incorporating virtual technologies. In 2020, the remote synchronized XR virtual performance "Mojito" during the Spring Festival Gala and "iQiyi"-invested XR virtual technology-produced immersive virtual concert "City of Reality and Illusion" by THE9 girl group marked the emergence of numerous virtual exhibitions and live shows utilizing XR technology. Simultaneously, virtual technology is also making its presence felt on offline stages with audiences. For instance, in the musicals "Alice in Wonderland" and "The OZ," "Immersive Virtual Environment Technology" (IVET) was employed for stage presentation under various visual perspectives. The application of virtual technology in the original musical "Death Note" utilized multi-angular visuals to expand the view from the "floor-wall-ceiling" in different ways.

In 2022, SKT presented the Metaverse musical "Lost Face 1895," seamlessly merging reality and virtual technology and directly integrating it into the interactive platform of the Metaverse. The emerging virtual broadcasting industry is fundamentally rooted in the live performance context, with a genre attribute characterized by collaborative structural elements in performing arts. So, how does the Metaverse specifically integrate virtual technology with Chinese traditional music? What are the manifestation forms of Chinese traditional music within the Metaverse?

## 2. Concept of the Metaverse

### 2.1. Music information visualization theoretical model from the metaverse perspective

#### Metaverse data structure

The term "Metaverse" is generally used to describe a "three-dimensional virtual space that realizes real-life and legally recognized social and economic activities." It is a composite word combining the transcendent meaning of "meta" and the universe of "universe"[2]. Its literal meaning implies a "universe beyond reality." While there is some controversy in the academic community regarding the origin of the concept of the Metaverse and there is no universally agreed-upon definition, it conceptually refers to a "virtual shared space" where both the online and physical worlds coexist.

Currently, we perceive the Metaverse as a virtual world that references the real world but exists independently of it. When Facebook founder Mark Zuckerberg rebranded the company as "Meta" and referred to the Metaverse as an intensely immersive "embodied internet," the Metaverse had already become a virtual space built on various technologies, including virtual and the internet, merging and coexisting with the real world or potentially existing independently from it. Real humans live in this space in the form of "virtual beings." Therefore, the concept of the Metaverse goes beyond the gaming realm, encompassing various sectors such as municipal offices, tourism, lifestyle consumption, music, healthcare, and wellness with the development of web3.0. It increasingly leverages the advantages of the transformation of "physical space" and the "interactive space." Overall, people's expectations for the Metaverse involve an open, shared, ubiquitous, and immersive virtual world.

## 3. Realizing human-computer interaction and information visualization of Chinese traditional music in the Metaverse

Roblox CEO Baszucki proposed eight fundamental characteristics of the Metaverse: identity, friends, immersion, low latency, diversity, ubiquity, economic systems, and civilization[3]. Futurists in the United States have outlined a four-category framework for the Metaverse, encompassing the enhancement and simulation of technology, the intrinsic direction of personal and external environmental focus, and categorizing the Metaverse into "augmented reality," "life-logging," "mirror worlds," and "virtual worlds"[4]. Among these frameworks, the content of virtual worlds, driven by the development of VR, AR, MR, and XR technologies, is classified as follows:

Virtual reality (VR): Users enter a virtual world by wearing devices, and observers can only see what the user experiences through screens. It emphasizes creating a virtual world that isolates users from the real world.

Augmented reality (AR): Virtual information and objects generated by computers are overlaid onto the real world. This can be experienced through electronic mobile devices such as smartphones and laptops.

Mixed reality (MR): A product of the fusion and intersection of the real and virtual worlds. In various science fiction movies, we often see technicians operating virtual projection control panels, which fall under this technology. The key feature is interactivity.

Extended reality (XR): Expanding reality through computer technology and wearable devices, XR combines the physical and virtual environments, creating an environment for human-computer interaction. It is a general term for the interaction between real and virtual technologies. All these different types of technologies fall under XR.

This indicates that XR = VR + AR + MR, meaning XR is no longer just a singular technological means but rather an artistic output. With the rapid growth and widespread adoption of XR technology, coupled with its continuous integration with Metaverse portal platform services, these four independently developing systems are breaking down boundaries and evolving toward integrated and composite forms. This transformation provides a new pathway for achieving human-computer interaction and information visualization of Chinese traditional music in the Metaverse. XR, characterized by "continuity," "realism," "interoperability," "concurrency," and "economic trends (compatibility)," is emerging as the mainstream in the virtual performance industry. Therefore, XR technology is the primary means to realize human-computer interaction and information visualization of Chinese traditional music in the Metaverse.

## 4. Characteristics of human-computer interaction and information visualization of Chinese traditional music in the Metaverse

### 4.1. Imaginary virtuality

The time and space in the Metaverse are composed of data[5]. It breaks the linear characteristics of time and the physical constraints of space, presenting features of boundlessness and infinite expansion. Humans can enter the virtual space of the Metaverse through digital avatars, completely overcoming the temporal and spatial barriers of the physical world, providing a new experience that transcends real-world perceptions. For instance, in the Metaverse, virtual music stars represent the virtualization of actor roles in musical works. Similar to 3D avatar creation applications, users can take photos or load images from their smartphones in relevant applications, generating a personalized virtual character. The appearance of the generated "avatar" can be freely customized, serving as an online entity and identity that can replace real personal information. This aligns with many singers releasing their virtual avatars on Metaverse platforms. An illustrative example is SM Entertainment in South Korea, which introduced the virtual personas of the new girl group Espa in 2020.

The group comprises four real members and four virtual avatars. Their debut song, “Black Mamba,” achieved 100 million views on YouTube in just 51 days after release.

### 4.2. Fan interactivity

The Metaverse operates on open-source code, providing an open ecosystem where users have the freedom to innovate and create[6]. Everyone, including musicians and fans, can become participants and creators in the Metaverse, engaging in scenario-based communication and interaction in virtual environments on gaming or portal platforms. When virtual musicians for Chinese traditional music emerge in the Metaverse, scenes of virtual and real interactions with fans unfold.

For example, on the Zepeto platform, users not only have the opportunity to directly meet popular music stars appearing on Metaverse platforms in virtual space but also create new communication platforms through various activities, including fan-verified photos. Fans can actively participate in various activities organized by their favorite musicians through their personalized avatars, sharing these activities on social media. Additionally, fans can design scenarios and environments for non-linear content development based on their preferences. SM Entertainment, in collaboration with the South Korean tech giant NAVER, introduced “Beyond Live,” a paid online concert featuring AR technology from the fan’s perspective. The transition between the real stage and virtual scenes was vividly demonstrated on the screen, combining the intimacy of fan participation with the new technology of large-scale concert production. Performers can showcase their talents on the actual stage, with synchronous audience support through light sticks, ensuring artist-fan dialogue and providing an interactive virtual concert experience that integrates high-quality audio-visual effects.

### 4.3. Integration of virtual and real

The Metaverse exhibits a three-step process of digital twinning, virtual nativeness, and the integration of virtual and real[7]. With the continuous integration of technologies like XR, the Metaverse has evolved from digital twinning to a stage where real and virtual information seamlessly blend. In this immersive environment of highly interconnected visual, auditory, tactile, gustatory, and olfactory sensory experiences, audiences can feel Chinese traditional music works in a Metaverse virtual concert—a seamlessly blended environment of reality and virtuality that is challenging to distinguish. Chinese traditional music creators are no longer limited to real-world experiences for their compositions. Instead, they utilize creative tools and software provided within the Metaverse to generate complex structures or expansive music performances. This allows for the complete integration of real-world performance content with virtual technology, forming various expressions of virtual Chinese traditional music concerts within the Metaverse.

The first virtual concert for popular music was hosted by American artist Travis Scott on the online gaming platform “Fortnite.” The event, with over 27 million interactive viewers and a peak concurrent connection of 12.3 million, garnered approximately 458 million video views, generating a revenue of 20 billion yuan. Renowned singer Ariana Grande also themed her face for a virtual performance on a gaming platform, attracting millions of viewers and holding the top position on the Billboard Hot 100 for eight consecutive weeks. The success of virtual concerts has had a significant impact on both the music and gaming industries, showcasing stages and performance planning that were previously impossible in reality, all in the form of the Metaverse. It also opens up possibilities for combining Chinese traditional music with gaming interfaces on Metaverse portals, creating significant stage space, expanding influence, and enhancing the efficacy of the Chinese traditional music industry.

### 4.4. Value expansion

Utilizing blockchain technology, specifically Non-Fungible Tokens (NFTs)[8], the Metaverse achieves economic self-circulation through smart contracts in an independent space, generating profits in the virtual

economy. On one hand, Chinese traditional musicians can monetize assets through the interaction of music works in the virtual and real worlds of the Metaverse, while fans, driven by their admiration for idols, collect and consume NFTs with future value expectations for the works. In turn, Chinese traditional musicians gain tangible economic returns. In essence, Chinese traditional music works achieve economic appreciation through value creation, providing continuous momentum for the sustained development of the Metaverse. NFTs are minted and distributed after intellectual property rights are secured through smart contracts or legal means[9].

Compared to traditional forms of music consumption, music NFTs possess intrinsic collectible value and introduce a new digital consumption form from the perspective of "earning income, having the right to adapt, and reselling." They provide a new medium for Chinese traditional music artists and creators to showcase their work. Musicians can not only collect their own works on platforms but also market them on the blockchain, allowing their fanbase to actively participate. For Chinese traditional music creators, NFTs make digital assets scarce, enabling creators to set prices for their work, circulate them in the secondary market, and realize higher value[10].

For virtual music platforms, NFTs facilitate more innovative ways for musicians and their works to interact, allowing the establishment of virtual interactive communities and providing a more direct, secure, and reliable connection for building artist communities[11]. On Spotify, the global leader in music streaming with the most users, "Meta Audio" integrates music onto the blockchain, offering a platform for both performance and listening that fundamentally transforms the music experience. Each unique and customized encrypted project in meta audio creates a non-replaceable token, serving as proof of digital ownership and authenticity for the encrypted asset. In 2020, musician Grimes, the wife of Elon Musk, auctioned 10 digital paintings titled "War Nymph" as NFTs, generating a revenue of 6.5 billion Korean won. In 2021, Japanese composer Ryuichi Sakamoto created an NFT from a precious live performance of "Merry Christmas Mr. Lawrence" during his battle against illness, consisting of 595 notes, each sold for 10,000 Japanese yen. These are exemplary cases of the value generated through the interaction between virtual and real in the Metaverse, and NFTs in the music domain provide significant value potential for the development of digital music.

# 5. Design of the human-computer interaction and information visualization system for Chinese traditional music in the Metaverse

## 5.1. Design concept

The design purpose of this XR platform system is to utilize XR digital technology for the multi-perspective digital stereoscopic creative design of Chinese traditional music, specifically focusing on the performance of Jiangnan Silk and Bamboo music and its instruments. The goal is to implement a virtual performance scene for Chinese traditional music, specifically Jiangnan Silk and Bamboo music, and achieve human-computer interaction for foundational knowledge and self-directed learning of Jiangnan Silk and Bamboo music through XR platforms[12]. The design follows the Y model, encompassing user needs, user goals, product features, and Maslow's hierarchy of needs, organically integrating design objectives with XR technology. The XR platform system should possess the following features: accessibility and fun, excellent interactive experience, aesthetic appeal and ease of operation, and scalability.

## 5.2. System function design

### 5.2.1. XR system main functions and components

The system functions are primarily divided into three major modules:

Fundamental knowledge module: This module focuses on showcasing and assessing the memorizable knowledge of the historical culture and music theory of Chinese traditional music, specifically Jiangnan Silk

and Bamboo music.

Virtual experiment module: This module is dedicated to self-directed composition and performance of Chinese traditional music, particularly Jiangnan Silk and Bamboo music. It aims to enhance creative capabilities and cognitive thinking[13].

Virtual scenario module: Creating a three-dimensional Silk and Bamboo museum and an H5 Silk and Bamboo animation, this module aims to recreate the performance scenes of Chinese traditional music, specifically Jiangnan Silk and Bamboo music, providing an immersive experience.

### 5.2.2. High-quality collection of Silk and Bamboo music audio and video in Chinese traditional music

Firstly, establish a library of audio and video recordings for Chinese traditional music, specifically focusing on Jiangnan Silk and Bamboo music. The audio is sourced from professional teachers of Chinese traditional Silk and Bamboo music to ensure both professionalism and originality. In the initial phase, determine the repertoire for recording; in the middle phase, formally record performances by inheritors and professional teachers, ensuring that the audio and video meet industry standards; in the final phase, refine and artistically process the recorded audio and video, creating a library of audio segments that can be creatively combined to form complete musical pieces. Due to the distinct and personalized performance styles of Jiangnan Silk and Bamboo musicians, the recording process involves continuous exploration of various recording styles and formats, ultimately resulting in a logically structured and effective audio and video library[14].

### 5.2.3. Immersive scene creative design for Jiangnan Silk and Bamboo music in Chinese traditional music

Virtual scenes are crucial elements for achieving immersion and enhancing the overall experience. Through thoughtful interactive design, users can become fully engaged in the interactive context of the virtual scene. The construction of virtual scenes aims to recreate the native environment of Jiangnan Silk and Bamboo music heritage, providing a dynamic display centered around inheritors and the original environment. Based on this concept, a 3D virtual museum for Jiangnan Silk and Bamboo music is created, visually adopting the architectural style of traditional Suzhou buildings. This includes the construction of a small theater and a stage, creating a sense of immersive presence for visitors. Animated elements are incorporated for virtual tours and interaction. Simultaneously, utilizing panoramic technology, full panoramic photography and roaming of the TaiCang Jiangnan Silk and Bamboo Music Museum are implemented[15].

### 5.2.4. Character and instrument model design for Jiangnan Silk and Bamboo music in Chinese traditional music

The character models are designed based on teachers specializing in Chinese traditional music at the music academy, adopting a traditional Chinese style (Q version). Performance actions are captured using motion capture technology, and the data is applied to virtual models to recreate the performances[16]. Simultaneously, an action database is established to serve as learning examples for learners. Regarding the Jiangnan Silk and Bamboo instruments, including the erhu, pipa, yangqin, and qudi, 3D modeling is employed, emphasizing the distinct features and shapes of each instrument. In the later stages of development, the instrument models can be interacted with in the engine, facilitating both appreciation of performances and learning about the instruments[17].

### 5.2.5. Interaction function design for the platform of Jiangnan Silk and Bamboo music in Chinese traditional music

In the human-computer interactive visualization system platform for Chinese traditional music, Jiangnan Silk and Bamboo, users can engage in interactive learning of the history, music theory, and performance of

Chinese traditional music Jiangnan Silk and Bamboo. Additionally, they can experience entertainment through role-playing in the form of music gaming related to the performance and creation of Jiangnan Silk and Bamboo music. The platform may include the following interactive components: interactive quizzes on cultural knowledge related to Jiangnan Silk and Bamboo, interactive learning of music theory for Jiangnan Silk and Bamboo instruments, interactive activities for performance and creation of Jiangnan Silk and Bamboo music, virtual roaming interactions within a Silk and Bamboo museum, and interactive animations related to Jiangnan Silk and Bamboo[18].

# 6. Construction of the XR system for Chinese traditional music—Jiangnan Silk and Bamboo

## 6.1. Key technologies and system architecture

### 6.1.1. Key technologies

The system is primarily implemented based on the following technologies:

First, Metaverse engine technology. The engine provides a software framework to handle event logic, collision detection, and physical properties. This system uses the Unity professional interactive engine for implementation, with programming done in the C# language.

Second, polygon modeling technology. Utilizing the 3D Max modeling tool to accomplish tasks such as digitizing models, lighting processing, animation, and rendering.

Third, mocap motion capture technology. Using inertial sensor motion capture devices to capture motion data from live performances of Jiangnan Silk and Bamboo and mapping it to corresponding models. Additionally, facial expression mapping is achieved through the use of ARKit facial tracking technology.

### 6.1.2. System architecture

Presentation layer: Users log in through various terminals such as PCs and mobile phones. The presentation layer serves as the human-computer interaction interface, responsible for managing user interactions with various functional modules on the Jiangnan silk and bamboo virtual platform[19].

Logic layer: This layer handles data business logic processing and formulates business rules. It mainly consists of scripts and visuals. The visual part involves UI interface, texture mapping, and modeling design, while the script part deals with audio processing, character animation design, etc. For example, in audio element extraction, fast Fourier transform is employed to convert audio data from the time domain to the frequency domain. Different frequency wave values are transformed into sound pressure levels, and after A-weighting transformation, the sound pressure level values are summed up.

$$SPL = 101g\sum_{i=1}^{n} 10^{SPL_i/10}$$

Among them: $SPL$ stands for sound pressure level, and $SPL_i$ represents a specific value of the sum of demand.

Engine layer: This layer is implemented using the Unity professional interaction engine, covering aspects such as physics settings, graphics management, event interaction, and data synchronization.

Data layer: This layer handles server setup, data recording and transmission, file storage, and other related tasks.

### 6.2. UI creativity

The UI interface serves as the entry point for human-computer interaction and is the primary element influencing user experience. The system is divided into main interfaces, guide interfaces, operational interfaces, etc. Firstly, in terms of UI creative design, the overall color tone of the interface is in dark shades, highlighting a vintage feel that reflects the charm of Jiangnan silk and bamboo. The main page features typical instruments of Jiangnan silk and bamboo, emphasizing the theme. The background incorporates line sketches depicting the scenery of Suzhou, the birthplace of Jiangnan silk and bamboo, with the city flower "rose" as an embellishment. The title buttons are crafted in the image of wooden prayer plaques from temples in Jiangnan, while the three-level titles use the strings of silk instruments as carriers[20].

In the implementation of UI interaction functions, the UGUI solution is adopted. Based on the interaction design process, the UI object framework is built in the Canvas and interactive events are implemented. Taking the scene-switching interaction function as an example, the response method is mouse click. The scene can be switched to the next scene and the exit button function can be simultaneously implemented by editing the event penetration script. Part of the script is as follows:

```
void OnPointerUp(PointerEventData eventData)
{
    PassEvent(eventData, ExecuteEvents.pointerUpHandler);
}
void OnPointerDown(PointerEventData eventData)
{
    PassEvent(eventData, ExecuteEvents.pointerDownHandler);
}
```

### 6.3. Model creation and optimization

This primarily involves three major parts: instrument modeling, character modeling, and scene modeling. Models are a crucial factor determining the user experience and immersion of the VR system, and their accuracy, precision, and level of optimization will directly impact the final outcome of the system.

#### 6.3.1. Instrument model creation

Emphasizing a realistic style to depict the instrument's image. Considering performance, the Physically Based Rendering (PBR) process is adopted to achieve high-to-low model processing, restoring a realistic style. The post-showcasing and explanation of instruments and scores involve key points of professional knowledge, and the model representation is based on the expertise of teachers and the research results from silk and bamboo professional books. Additionally, animations corresponding to the instruments are designed, aiming to later restore the sound effects of instrument performances. Some instrument models are shown in **Figure 1**.

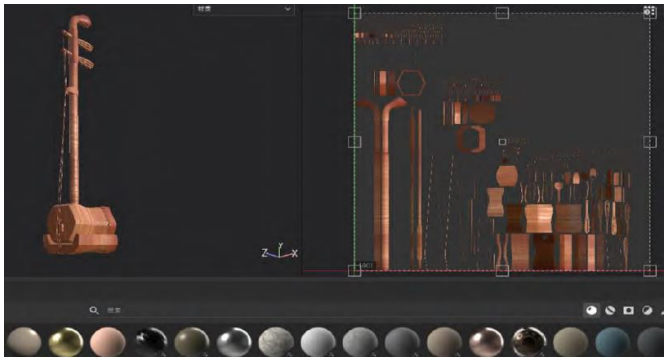

**Figure 1.** Modeling of some Silk and Bamboo instruments in Jiangnan.

### 6.3.2. Character modeling and optimization

The character models are mainly based on several traditional Chinese music teachers, designed in a Q-version Chinese style. Simultaneously, combining the character with instrument models, including performance animations, and coordinating with the pre-recorded audio library, the live process of silk and bamboo performance is recreated. Using motion capture devices, the performance actions of the performers are captured, and the motion data is bound to the corresponding character models. Facial capture involves determining attributes such as the size and position of facial features, calculating their geometric characteristics based on this foundation, and ultimately forming an overall facial feature vector.

Some API methods include:

public void RunWithConfig(ARKit Face Tracking Configuration config);

public void RunWithConfigAndOptions(ARKit Face Tracking Configuration config, Unity ARSession Run Option run Options);

public delegate void ARFaceAnchorAdded(ARFaceAnchor anchorData);

public static event ARFaceAnchorAdded ARFaceAnchorAddedEvent.

During the creation of character models, optimization is necessary. The model needs to be wired overall, refined in areas of the upper limbs that need to be emphasized, and effective control of face numbers and occlusion treatment in areas that do not participate in action playing.

### 6.3.3. Scene modeling and optimization

The scene is based on a traditional Chinese music hall, creating a three-section courtyard with the distinctive features of the Jiangnan region. The focus is on the central stage and the adjacent scene for dramatized musical performances. Geometric modeling is employed to construct the virtual scene. Mesh wiring is used to control the overall model, and independent modeling is carried out for scene-specific structures and small scene props, followed by overall assembly. Scene optimization remains a priority as it determines the smoothness of system operation and the immersive experience. In addition to optimizing modeling techniques, the following measures have been taken:

LOD (level of detail) technology: This involves switching model precision within different viewing ranges.

Occlusion culling technology: Static objects are set to be occluded, reducing the draw call count and improving rendering efficiency.

Lighting system optimization: Lightmaps are used to minimize real-time lighting in the scene.

Layer culling distance technology: This involves culling small objects in the distance from the camera's line of sight, reducing the call count.

Here is an example script:

```
void Start()
{
    float[] distances = new float[32];
    distances[6] = 7;
    //Assign the array to the camera's layer Cull Distances
    Camera.main.layerCullDistances = distances;
}
```

This script establishes small object culling layers and is attached to the scene. When the distance is less than or equal to the camera's farClipPlane, small objects will be hidden.

### 6.4. System platform interaction implementation

The system is ultimately published based on the Web GL standard, ensuring universality and ease of promotion. Initial models are imported into the Unity platform to complete basic terrain construction and program development. This involves implementing interactive processes such as system module switching, UI navigation, and model display. A database is established to manage and record user data and assessment results. The design of interactive processes takes into account the logical closure of the work while enhancing the user's smooth experience and immersion. For instance, in the processing of musical instrument sounds, the sound pressure calculation formula is used:

$$G_{dB} = 201g\frac{X}{X_0}$$

Specifically implemented portions of the script are as follows:

```
int i;
float sumVoice = 0.0f;
for (i = 0; i < SAMPLE_SIZE; i++)
{
    sumVoice += SZsamples[i] * SZsamples[i];
}
float rms = Mathf.Sqrt(sumVoice/SAMPLE_SIZE);
float dB = 20 * Mathf.Log10(rms/0.1f);
//Other code...
```

## 7. Conclusion

The human-computer interaction and information visualization of traditional Chinese music in the metaverse can play a facilitating role in the development of traditional Chinese music. The advantages of human-computer interaction and information visualization of traditional Chinese music in the metaverse are as follows:

Firstly, it can break through the limitations of time, space, and instructional resources, providing a replicable "real" environment for the development and inheritance of traditional Chinese music through the construction of highly realistic scenarios.

Secondly, it can enhance the bidirectional interaction of learning traditional Chinese music, effectively mobilizing learners' active interactive behaviors, and enhancing the sense of presence and experiential learning.

Thirdly, by simulating and restoring real performance scenes of traditional Chinese music, and incorporating game-like composition and role-playing, it brings visual and auditory impact, enhances immersion, combines education with entertainment, and increases learners' interest.

At the same time, the metaverse is a major means of information exchange and communication for modern youth. This platform can attract more young people, thereby expanding the dissemination breadth of traditional Chinese music. The realization of human-computer interaction and information visualization of traditional Chinese music in the metaverse is a fusion of art and technology, providing a new model for the inheritance and education of traditional music genres.

## Author contributions

Conceptualization, YC and JP; methodology, YC; software, YC; validation, YC and JP; formal analysis, YC; investigation, JP; resources, JP; data curation, YC; writing—original draft preparation, YC; writing—

review and editing, JP; visualization, YC; supervision, JP; project administration, JP. All authors have read and agreed to the published version of the manuscript.

## Conflict of interest

The authors declare no conflict of interest.

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