Research on the Construction and Application of Erhu Performance Technique Database in Shanxi Textile Intangible Cultural Heritage Music

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ABSTRACT This study focuses on erhu performance techniques in Shanxi textile-related intangible cultural heritage music and constructs a digital technique database through fieldwork, literature collation, and audio-visual digitization. Performance data from textile labor music, folk tunes, and local opera-related materials were collected, structured, and annotated to form a multidimensional information resource. The database records technique categories, audio segments, video evidence, regional sources, and heritage project metadata, and supports retrieval, teaching, preservation, and creative reuse. The study further discusses the application of the database in intangible cultural heritage protection, music education, dissemination, and artistic innovation. From an engineering perspective, the work transforms traditional performance knowledge into a searchable digital signal resource, providing a basis for acoustic feature extraction, multimedia transmission, and intelligent cultural archives. The framework can be extended to wireless audio-visual acquisition and electromagnetic-wave-based communication environments in digital heritage systems, provided that the technical infrastructure maintains recording fidelity and data integrity. The study offers a practical path for precise documentation and living inheritance of traditional music resources.

INDEX TERMS erhu techniques,digital database,audio signal analysis,wireless transmission,intangible cultural heritage

I. INTRODUCTION

BEING one of the significant pillars of Chinese civilization, Shanxi has significant resources of cultural heritage, which is intangible. Textile related intangible cultural heritage music is one of the components of local culture among them, which incorporates different art forms into it including work-songs, folk tunes, and opera music with different regional attributes and cultural implications. Such an accompaniment instrument as the erhu, which is common in this kind of music not only reflects the fundamental form of musical manifestation but also embodies the traditions and aesthetic features of music in a particular socio-historical procession. But modern changes of living style and absence of the old-time production scenes entail the crisis of inheritance of most kinds of music and their methods of performance that rooted deeply in the textile labor. Besides, the current protection of intangible cultural heritage work typically focuses on the general recording of audio and videotape, not particularly extracting and processing the most important technical aspects, such as performance methods. Hence, building a database that dedicated erhu playing techniques in the field of intangible cultural heritage music by the Shanxi textile industry would both fill gaps in research in this area, as well as become a valuable baseline to the digital preservation, pedagogy, and modern innovation of the intangible cultural heritage resource. The article is composed on the ways of the database construction, the content of the data, and the sphere of its usage with the aim to develop a reference to research and practice in the same sphere.

II. RELATED WORK

In recent years, the research and practice of Erhu art has shown a clear trend of expanding from the analysis of ontological skills to the direction of interdisciplinary, digital and application-oriented development. Permana et al.[1] used computer vision and machine learning technology to automatically identify the wrong movements in Erhu performance and provide auxiliary feedback for learners. Kimsanov and Mahmudjonov [2] analyzed the artistic characteristics of Russian orchestral works and explored their application in the teaching syllabus of music schools. At

the same time, based on teaching experience, they discussed how these works specifically affect the development of students' playing skills, musical understanding and ensemble ability. Xu [3] analyzed the dialectical relationship between Erhu playing skills and musical understanding from the perspective of music aesthetics and performance theory . Song et al. [4] compared the different emotional characteristics perceived when the same musical fragment was played by these two instruments with different techniques. As a traditional Chinese instrument, Erhu is facing the challenge of how to maintain its vitality and revitalize itself in the contemporary musical context and global cultural wave. Qiaoyi [5] analyzed the integration practice of Erhu with different musical styles.

Chinese pop music is actively exploring the integration with traditional culture. Jiang and Hong [6] analyzed the use of the erhu, its musical function, and its interaction with pop music arrangement, and explored the artistic effects and cultural significance of this integration. Xia et al. [7] compiled a set of "Shanxi Folk Song Erhu Ensemble Workbook" suitable for erhu students of Shanxi Art Vocational College. Weifen et al . [8] showed that through appropriate repertoire selection, technique adjustment and targeted practice, Chinese students can effectively learn and play Thai music with the erhu. Kakihara et al. [9] found that in the instrument training program, the improvement of the elderly's musical performance skills was significantly positively correlated with their performance improvement on specific cognitive tasks. Ugli [10] explored and designed a set of teaching activities and lessons using various percussion instruments based on music education theory. However, the research object lacks focus and in-depth analysis of the heritage element of erhu playing techniques in specific categories of intangible cultural heritage . This paper constructs a database of erhu playing techniques that combines academic rigor with technical practicality, aiming to provide key basic resources and methodological support for the precise protection, living inheritance, and contemporary innovation of intangible cultural heritage music.

III. METHODS

A. DATA ACQUISITION AND PREPROCESSING

The data collection approach used in this study is multi-source, which involves three different central channels, namely fieldwork, literature review and digitization of the audio-visual resources available. The critical textile intangible cultural heritage sites in the Shanxi Province including Jinzhong, Lululing and Yuncheng were all in fieldwork. Erhu performance examples that are connected to textile labor scenes were gathered through participation observation and the use of semi-structured interviews. The data collection plan was elaborated, as well as the sampling points were distributed in every region, the time data were to be collected, and the criteria on which respondents were to be selected. Looking at the hearing impairment and poor physical capacity of old performers, a step by step data collection plan was adopted with each continuous performance taking not more than 20 minutes and a reasonable interval between two to maintain a good quality of data. To ensure optimal sound quality while considering the practicalities of fieldwork, relatively quiet indoor environments were prioritized for data collection. For outdoor recordings, a Zoom H6 digital recorder and a Sony PXW-Z90 camera (48kHz/24bit sampling rate, 1080p/60fps video resolution) were used for high-quality audio and video recording, with windproof covers and directional microphones employed to minimize environmental noise interference. However, it must be noted that outdoor recordings can still introduce uncontrollable environmental factors. To minimize their impact on analytical accuracy, all outdoor recordings underwent rigorous environmental noise assessments during post-processing, and severely affected samples were marked or removed to ensure the data entering the database met the reliability requirements for subsequent acoustic feature analyses such as pitch and dynamics. With respect to literature collection, local chronicles, music collections and handwritten scores in older generations of artists, were sorted out to filter out descriptions and musical examples of erhu playing techniques. Consideration was specifically given to the comparison and collating the various versions of the literature to provide the correctness of the information. There are existing audio-visual materials primarily in analog format not to mention those in video format that are archived in the cultural center and converted to digital by using ADC equipment and further refined by the removal of noises and signal enhancement. The preprocessing phase involved the creation of a uniform data processing process, which includes harmonization of files formats and standardization of metadata, and quality check. The name and label of all the collected raw data worked in a unified manner with the metadata putting basic details, such as performer, location of gathering, music genre, and date of gathering, among other details to correct the data to be stored later in structured form [11-12].

The aforementioned data collection work yielded raw data from 35 field surveys, covering 14 intangible cultural heritage projects related to textiles in Shanxi Province. The total audio duration was 1050 minutes, and the total video duration was 1120 minutes. This scale provides a sufficient sample basis for subsequent technique extraction and analysis. Regarding data quality control, a three-tiered review mechanism was established, including on-site preliminary review, laboratory technical review, and expert content review, to ensure that each piece of collected data met research requirements.

B. EXTRACTION AND ANNOTATION OF PERFORMANCE TECHNIQUES

According to the data preprocessing, the features of the techniques were calculated using the gathered audio and video data. The audio was examined with the help of the LibROSA toolkit that provided the acoustic features such as

TABLE 1. Statistical Table of Field Survey Data on Erhu Performance Techniques in Shanxi Textile Intangible Cultural Heritage

Area	Collection sessions	Audio duration (minutes)	Video duration (minutes)	Number of intangible cultural heritage projects involved
Jinzhong	12	360	380	5
Lüliang	8	240	260	3
Yuncheng	10	300	320	4
Other regions	5	150	160	2
Total	35	1050	1120	14

the pitch curves, dynamic range, and switching the technique frequency. In common erhu playing techniques, such as pushing the bow, pulling the bow, vibrato, glissando, and striking the string.

Characteristic parameter thresholds are defined. For example, the threshold for the rate of pitch change (unit: semitone/second) in glissando is set to 0.8. This value is based on the statistical analysis of glissando samples from multiple performers in the preliminary experiment, and is jointly determined by the subjective evaluation of three experts to ensure that fast glissando movements can be classified as effective glissando techniques. To improve the accuracy of feature extraction, this study designs a multi-feature fusion method. This method first extracts a total of 32-dimensional low-level acoustic features from the time domain (e.g., short-time energy, zero-crossing rate), frequency domain (e.g., spectral centroid, Mel-frequency cepstral coefficients (MFCCs), and time-frequency domain (e.g., wavelet packet energy spectrum). Then, these features are combined into a high-dimensional feature vector using feature layer concatenation, and principal component analysis (PCA) is used to reduce its dimensionality to 16 dimensions to eliminate redundancy. Finally, based on the dimensionality-reduced feature vector, a trained support vector machine (SVM) classifier is used to comprehensively determine the technique category of each audio frame, thereby achieving deep fusion of time-domain, frequency-domain, and time-frequency-domain features. Video interpretation involved the OpenCV framework to follow and identify visual cues which include the movements of the performer including the use of bows, positioning of fingers and fingers, where the alignment of when right hand bows change versus the left hand fingers change is focused on. In video processing, a joint detection algorithm based on human pose estimation is employed to accurately identify key parts of the performer's body, such as hands and elbows, thereby enabling more accurate analysis of performance movements. To address common occlusion issues in video analysis (such as the bow obscuring hands or body), a trajectory prediction and smoothing algorithm based on temporal information is introduced. When key joints are briefly occluded, the system uses coordinate information from preceding and following frames for linear or Kalman filter interpolation to maintain the continuity of joint trajectories and ensure the integrity of technical feature extraction even under occlusion conditions. All the findings of the feature extraction process were cross-validated by three professionals who had a history of more than 10 years of playing erhu to take care of consistency and accuracy of annotation. In the process of annotation, an specialized annotation tool was created, which can display waveforms, spectrograms and time-synchronized video, increasing the efficiency of annotation. The annotation system is adopted hierarchically. The major technique categories (e.g. bowing techniques and fingering techniques) are the first layer, the technique names (e.g. staccato and vibrato) are the second layer, and the third layer is the technique parameters (e.g. intensity and duration). To guarantee the uniformity of annotation standards, an annotation guide was assembled, which explicitly outlines the standard on which judgment is to be made as well as the formula that is to be used in calculating the parameter of every technique, and an annotation training session was arranged. The annotation outcomes are returned in the form of a JSON and also indexed and linked to the respective audio and video files [13-14].

The aforementioned annotation system enables a multi-dimensional description of erhu playing techniques, laying the foundation for subsequent database query and analysis functions. Regarding annotation quality assessment, a consistency check method was employed to calculate the consistency rate of annotations for the same segment by different annotators, ensuring the reliability of the annotation results.

C. DATABASE ARCHITECTURE AND FUNCTION IMPLEMENTATION

The database is developed based on MySQL relational database management system, and mainly it was composed of core data tables, including user information, intangible cultural heritage projects, performance techniques, and audio/video files. The single most significant element of the database is the performance techniques table which is the center and other tables are connected by the foreign key and guarantee consistency and integrity of data. The database design complies with the third normal form of data design, which minimizes redundancy of data as well as enhances data integrity. In particular, to meet the nature of erhu performance methods, a data representation that allows a multi-level and multi-dimensional query is integrated, which contains classification systems founded on region, intangible cultural heritage project, type of technique, and time. The database front-end is based upon the Python Flask framework used to create a web interface application and includes multi-condition query, data visualization, and export capabilities. The interface is user-friendly and is designed to give priority to the user experience, search interface is intuitive, whereby browsing is arranged in a hierarchy and

TABLE 2. Erhu Performance Technique Labeling System

Techniques	Specific techniques	Parameter indicators	Example of labeling (numerical range)
Bow Technique	Staccato	Peak intensity (dB)	75–85
Bow Technique	Trembling bow	Frequency (Hz)	8–12
Fingering	Portamento	Pitch changes (semitones)	1–3
Fingering	Sound	Trigger duration (ms)	80–120

displays are visual. It allows the users to search on the basis of keywords like region, intangible cultural heritage project, and the type of technique and allows viewing audio/video clips online. Extended search capability has been added as well including Boolean search logic and fuzzy search to fulfill the multifaceted query requests of professional user. The database holds API interfaces to be incorporated once more in the future to teaching platforms or creative software. Role-based access control (RBAC) is configured in order to have permission flexibility to differentiate levels of permission of administer, researcher, and public users to maintain data security. The database is installed on a local server and backup and version are taken periodically. Regarding the performance optimization, there is the development of an indexing mechanism to index the most used query fields to enhance the efficiency of queries; caching technology is also employed; it relieves the direct access load on the database [15] .

IV. RESULTS AND DISCUSSION

A. OVERVIEW OF DATABASE CONTENT

Based on the above methods, this study established an Erhu performance technique database containing 14 textile-related intangible cultural heritage items in Shanxi Province. 1024 technical records were considered, which contained all metadata, parametric characteristics and audiovisual indexes. The most common bowing distribution techniques are bowing technique (62%) and fingering technique (38%). Staccato, vibrato, portamento and vomiting are some of them, which differ in playing style from region to region. During the demonstration, Jinzhong focused on changes in bow power, while Luliang focused on decorative fingering. This distribution has a lot to do with the music and musical tastes of each region. Jinzhong's textile work songs have specific rhythms and require strong pulling of the bow, while Luliang's songs are gentler and focus on fine fingering. The database is very structured and facilitates data aggregation and statistics for various perspectives such as technical names, regions and music genres. In addition to mere information about technique, the personal stylistic characteristics of each performer are also present in the database, and this source will allow obtaining a wealth of information regarding the analysis of specific aspects of an individual performer's artistry. It is particularly worth mentioning that the database also contains records of performers' techniques in various periods, allowing the historical development of techniques to be studied.

TABLE 3. Statistics on the Contents of the Shanxi Textile Intangible Cultural Heritage Erhu Performance Techniques Database

Technique types	Number of records	Percentage (%)	Main distribution areas
Bow Technique	635	62	Jinzhong and Yuncheng
Fingering	389	38	Lüliang and other regions
Total	1024	100	-

The statistical results show that bowing techniques dominate in the erhu performances of Shanxi textile-related intangible cultural heritage. This is closely related to the strong rhythmic nature of textile work and the need to emphasize beat. The differences in the distribution of techniques across different regions reflect the profound influence of regional culture on musical style. Further analysis reveals that the specific expression of the same technique also varies in different regions. For example, the staccato bowing in Jinzhong is shorter and more forceful, while in Yuncheng it is relatively softer. These subtle differences are an important manifestation of local characteristics.

B. APPLICATION OF DATABASES IN INTANGIBLE CULTURAL HERITAGE PROTECTION AND TEACHING

Within the protection of intangible cultural heritage, this database has offered technical support to the correct recording and preservation of Shanxi textile related intangible cultural heritage music. Generally the protection methods are concerned with overall recording but this database with the extraction and annotation of techniques realizes the preservation of performance skills in its anatomical aspect and thus aids in avoiding the loss of technical detail in the flow of the transmission process. In particular, one can use the database to develop digital archives, document the performance features of each musician and even determine the lineage of spreading the technique with the help of data analysis. In cases where the techniques are endangered, the database is able to fully retain the parameter characteristics and performance context and this forms a foundation onto which they can be restored in future. Eruhu professional teaching can be used with the aid of the database in the educational sphere. By asking local variations of particular practices, teachers are able to demonstrate different performance styles of the same technique to the students. As an illustration, in explaining the vibrato technique, the powerful and tough style of the Jinzhong region can be drawn against the delicate and tender style of the Luliang region, which increases the awareness of the style of music among students. Moreover, the videos and audio resources in the database can be utilized directly on the production

of the lesson plans or the development of online courses enhancing the accessibility and standard of the teaching materials. Initiative teaching application trials have been held in Shanxi Vocational College of Arts. Findings indicate that the students who attended teaching utilizing database have demonstrated a great enhancement in mastering techniques and performance. A database can also be used to facilitate a customized approach to the planning of learning paths, by suggesting an appropriate practice material and demonstration samples depending on the learning progress of students and their attributes.

C. THE POTENTIAL OF DATABASES IN ARTISTIC INNOVATION

This database will be very valuable at the artistic innovation aspect of composition and performance of music. Traditional music can be used by the composers in the composition of modern music by seeking the technical peculiarities of the various regions e.g. converting the staccato rhythm of textile working songs to rhythmic samples of electronic music. The analysis of technical parameters provides a way to optimize the performance of a performer, i.e., the mention of the dynamic control of a traditional glissando in the performance of contemporary works with erhu. Also, the open interface of the database facilitates interdisciplinary cooperation, e.g., the integration with such disciplines as computer music to create intelligent performance generation systems founded on traditional methods. These applications help in diversifying the traditional music besides encouraging the creative transformation of intangible cultural heritage resources within the contemporary cultural context. In particular, the database can be used to support a number of innovative practices: first, the database can support new media art, where techniques are combined with visual arts, dance.

V. CONCLUSION

This paper focuses on the erhu playing techniques within the intangible cultural heritage music of Shanxi textile industry. Through systematic data collection, feature extraction, and database construction, a specialized resource database with both academic value and application potential has been established. A complete technical route was established during the research process, from multi-source data collection to multi-level feature annotation, and finally to the implementation of a structured database. Each step emphasized the scientific nature of the methods and the reliability of the results. The database covers erhu playing techniques from major textile intangible cultural heritage areas in Shanxi, preserving not only the techniques themselves but also their cultural context and usage scenarios. At the application level, this paper discusses in detail the specific implementation paths and expected effects of the database in multiple fields such as intangible cultural heritage protection, teaching and transmission, and artistic innovation, and verifies its feasibility through preliminary practice. The research shows that a technique database based on digital technology can effectively solve the problem of insufficient recording of technique elements in intangible cultural heritage protection and provide support for teaching, creation, and other practical fields. Future work will focus on expanding and deepening the database, including adding more intangible cultural heritage projects, optimizing technique recognition algorithms, and developing mobile applications to further enhance its academic influence and social utility. Meanwhile, it is hoped that this research paradigm can provide a reference for the protection and inheritance of other categories of intangible cultural heritage. It is particularly noteworthy that, with the development of artificial intelligence technology, the database can also be combined with machine learning algorithms to achieve automatic identification and classification of techniques, further improving research efficiency. Furthermore, the database's open and scalable design also makes its application possible in different fields, such as cross-disciplinary integration scenarios like music therapy and cultural tourism.

AUTHOR CONTRIBUTIONS

Kun Liu designed, collected and analyzed the data, and drafted the manuscript. Kun Liu conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Kun Liu participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

FUNDING

This research received no external funding.

ACKNOWLEDGEMENTS

Not applicable.

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