SIN-CHN SCIENTIFIC PRESS PTE.LTD.

Molecular & Cellular Biomechanics 2025, 22(2), 986.
https://doi.org/10.62617/mcb986

Article

Resource construction of intelligent design based on artificial intelligence bio-perception in the protection of intangible cultural heritage

Bin Wang

School of Art, Zhejiang Yuexiu University, Shaoxing 312000, China; 20231024@zyufl.edu.cn

CITATION

Wang B. Resource construction of intelligent design based on artificial intelligence bio-perception in the protection of intangible cultural heritage. Molecular & Cellular Biomechanics. 2024; 22(2): 986. https://doi.org/10.62617/mcb986

ARTICLE INFO

Received: 3 December 2024
Accepted: 18 December 2024
Available online: 24 January 2025

Abstract: The protection of intangible cultural heritage (ICH) is not only respect and protection for traditional culture, but also plays a vital role in cultural inheritance, social identity, historical memory, economic development, and innovative vitality. With the rapid advancement of globalization and modernization, ICH is also facing unprecedented challenges. However, the traditional protection of ICH has problems such as focusing on static physical protection, insufficient information storage, limited transmission, insufficient modern transformation and innovation, excessive restoration of traditional elements and conservative protection. In response to the above problems, this paper designs an ICH resource construction system based on artificial intelligence (AI) biological perception. It can perceive ICH data through multimodal biology, store and reproduce it, perform feature analysis based on biological emotions and emotional interactions, capture the inheritance logic and emotional connotation of culture, and drive the digital modeling of ICH resources with intelligent design. Dynamic ICH content can be superimposed on real scenes to facilitate education and dissemination, and personalized ICH story content can be recommended based on user preferences to enhance the display and dissemination capabilities of ICH. The results show that the system uses multimodal perception and stores more than 100,000 ICH data items in four major categories and multiple subcategories, and designs a unique interactive tag cloud for users to choose from. When making recommendations for users, it recommends 200 ICH contents to users from the sorted list simultaneously, and the proportion of users clicking on the recommendations reaches 85%, while also achieving the widespread dissemination of ICH in Asia. Compared with traditional ICH protection, this study has achieved efficient digital storage of ICH content, strong modern conversion, and ease of acceptance by users. The scope of dissemination is also wider. This shows that the use of AI and biosensing technology in ICH protection is effective and can contribute to better preservation, publicity and promotion of ICH.

Keywords: intangible cultural heritage; artificial intelligence; multimodal biosensing; resource construction; intelligent design

1. Introduction

Intangible cultural heritage (ICH) is a valuable asset of human history and culture [1–3]. It carries traditional knowledge, skills, performing arts and folk customs, and has extremely high cultural value and historical significance. However, with the advancement of social change and modernization, ICH is facing the risk of disappearing gradually. Especially in the rapidly developing information age, traditional protection methods (such as oral inheritance, field records, etc.) have gradually shown their limitations and are unable to effectively preserve and transmit these precious cultural resources. At present, traditional cultural protection methods are not only unable to cope with the diversity and complexity of cultural heritage, but also unable to meet the new demands for cultural inheritance in the digital age. Therefore, how to use advanced technical means, especially AI technology, to improve the efficiency and quality of ICH protection has become a research hotspot and challenge.

Existing studies have shown that digital technology, virtual reality (VR) and augmented reality (AR) have played an important role in the protection and dissemination of ICH [4–8]. Many scholars have proposed that advanced digital technology can be used to transform traditional forms of cultural heritage into digital resources for easy preservation, display and dissemination. For example, Chen and Ke [9], based on the difficulties and current situation of Suzhou embroidery dissemination, used the social networks of the digital age to broaden the ways to protect the inheritance of Suzhou embroidery. Lo et al. [10] used 3D interactive media technology to spread Hakka Kung Fu in an event called “Three Hundred Years of Hakka Kung Fu: A Digital Vision of Tradition and the Future”. Damala et al. [11] introduced the MUSETECH model to build a digital museum, which includes mobile museum guides, augmented and virtual reality applications, hands-on museum interactions, educational entertainment applications, etc. Nikolakopoulou et al. [12] used spatial augmented reality (SAR) technology to design a projection mapping installation for the Mastic Museum in Chios, Greece, linking the material and ICH of Mastic and related villages through vivid illustrations. Buyuksalih et al. [13] used 3D modeling and virtual reality technology to develop an immersive and interactive cave VR visualization of the İnceğiz Cave in Istanbul, Turkey. Trunfio et al. [14] studied the theoretical content of using VR and AR to improve museum exhibition content, organization, reception staff and other services, which has management significance for the improvement of future museum management. Karuzaki et al. [15] used AR technology to help tourists find information about the cultural heritage collections of the Lampung Museum and developed an application to display 3D objects and provide relevant collection information. Jiang et al. [16] experimented with the effectiveness of AR in enhancing the memory of tourists’ tourism experience at the heritage site and pointed out that tourism experience is the mediator between tourists’ attitude towards AR experience and behavioral intention. Banfi et al. [17] improved the creation of the XR experience of the Basilica of Sant’ Ambrogio in Milan through 3D exploration, 3D modeling, building information modeling, and extended reality (XR) technologies, achieving a new level of interaction. However, existing research focuses on the application of a single technology, lacking the comprehensive application of multiple advanced technologies and their in-depth exploration in resource construction, resulting in the failure to maximize the application effect of technology and the protection benefits of cultural heritage.

In order to make up for the shortcomings of existing research, scholars have begun to pay attention to the cross-domain integration of intelligent design and AI technology in recent years. For example, Xu [18] emphasized the role of big data and AI in the dissemination of cultural heritage, and analyzed the ICH dissemination opportunities under the background of big data and AI. Based on an in-depth study of the horse-faced skirt of the Qing Dynasty, Yue et al. [19] proposed to introduce the horse-faced skirt into the virtual world by combining AI, digital economy and other high-tech means to activate digital cultural heritage. After outlining Europe’ s policy on the digitization of cultural heritage, Di Giulio et al. [20] emphasized the potential of intelligent design technologies such as 3D laser measurement, large-scale crowd detection tools and cultural heritage analysis in the field of cultural heritage protection. Stapleton et al. [21] proposed a digitization process to encode artifact attributes into XML and link them to the ontology to describe the intangible and tangible cultural heritage of UNESCO. Tian et al. [22] developed a program called PoeticAR based on AR for Jichang Garden, which can present poems based on natural scenery, enhance tourists’ cultural aesthetic tourism experience of Jichang Garden and improve their understanding of cultural heritage. Xu et al. [23] studied and constructed a self-sufficient question-answering system for Nanjing Yunjin digital resources based on knowledge graph, which greatly facilitated the retrieval and utilization of Yunjin knowledge and contributed to the inheritance, promotion and application of Yunjin culture. Based on their research, Munster et al. [24] emphasized the scope of AI in the field of culture and innovation, as well as the latest progress and challenges of AI in the cultural field. Yin [25] used image recognition technology to help intelligently identify the authenticity and age of black pottery when studying the inheritance and development of black pottery culture. Li et al. [26] proposed a Chinese cultural heritage computing framework based on previous research on cultural resources. They demonstrated the corresponding computing methods for different stages of Chinese cultural heritage protection and development through three modules: data acquisition and processing, digital modeling and database construction, and data application and promotion. Deng et al. [27] explored the innovative application of AI and machine learning algorithms in the field of ethnic costume design, with a special focus on Miao women’ s costumes. Although these studies have provided new ideas for the protection of ICH, in actual operation, there are still problems such as low technical integration, distorted cultural expression, and communication barriers due to regional and language differences.

This study designs a new ICH resource construction system based on AI and bio-perception technologies [28–32]. The system mainly consists of three modules, namely, multimodal bio-perception module, AI analysis module, and intelligent interactive recommendation module. The multimodal bio-perception module uses biological data acquisition equipment to collect and store data of different types of ICH content and conduct preliminary data processing. The AI analysis module further analyzes and processes motion, audio, text, image and texture data, and stores different types of ICH content in different forms in the system. The intelligent interactive recommendation module is mainly for users, providing intelligent recommendations for ICH that users are interested in and designing a one-click recommendation function to spread ICH content. After analyzing the system background data, the number of ICH content data items in four major categories and multiple subcategories stored in the system has exceeded 100,000, and more and more users are using the one-click recommendation function. The recommendation function of the system is also very powerful. If 200 ICH contents are recommended to users, the recommendation rate can reach 85%. Users are happy to browse ICH contents and spread them. At the same time, the spread of ICH contents is no longer limited to China, but is widely spread across Asia. This shows that it is effective to use AI and biosensing technology to build resources for ICH protection, and the research content of this paper can also contribute to the protection and dissemination of ICH.

2. Multimodal biosensing module

2.1. Data collection

Table 1 shows the data acquisition module table of the multimodal biosensing part. There are five modes in the table, namely visual mode, auditory mode, language mode, action mode and physiological mode. Each mode corresponds to its corresponding device name and the purpose of the mode. For example, data acquisition of the visual mode requires the use of high-definition cameras and image sensors. Its purpose is to capture the scenes, movements and appearance characteristics of ICH performances. Data collection in the auditory modality requires the use of highly sensitive microphones to record audio signals. Data collection in the language modality requires the use of text entry tools to collect language expressions in ICH stories. The data collection of motion modalities requires the use of motion capture equipment, the purpose of which is to analyze the motion trajectory, posture, and movement rhythm. This paper collects data from different modalities to ensure the diversity and richness of the collected information, preparing for the subsequent data processing, fusion, and analysis.

Table 1. Data collection modality table.

Module Name	Related Equipment	Purpose
Visual Modality	Camera, Image Sensor	Capturing the scenes, movements and appearance of ICH performances
Auditory Modality	Sensitive Microphone	Record audio signals, including speech, background music, and ambient sounds
Language Modality	Text Entry Tool	Collect language expressions in ICH stories, such as narration, lyrics or explanations
Action Modality	Kinect, IMU	Analyze movement trajectory, posture and movement rhythm
Physiological Modality	Heart Rate Belt, Brainwave Devices	Understand the emotional or physiological responses associated with ICH

2.2. Data processing and fusion

This paper studies the way to deal with missing values by using mean filling, that is, using the mean of the column to fill the missing behavioral data. The mean formula is:

$$x_{filled} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{1}$$

In Equation (1), x_{filled} is the filling value, x_i is the *i*-th data in the column, and n is the number of samples in the column.

This paper studies the way to deal with outliers by using the *Z*-score method, that is, calculating the *Z*-score of each data point and removing outliers that exceed the threshold.

The calculation formula of Z-score is:

$$z_i = \frac{x_i - \mu}{\sigma} \tag{2}$$

In Equation (2), μ is the mean of the data of this category, σ is the standard deviation of the data of this category, and x_i is the sample value.

This paper uses the dynamic time warping (DTW) algorithm to synchronize the time of data of different modes [33]. It uses nonlinear alignment to find the minimum distance after deformation (distortion) on the time axis, so that the two sets of time series match as much as possible.

Dynamic time warping algorithm formula:

$$D(i,j) = dist(x_i, y_j) + min(D(i-1, j-1), D(i-1, j), D(i, j-1)) \tag{3}$$

In Equation (3), $D(i,j)$ refers to the distance between the i-th and j-th modal points, and $dist(x_i, y_j)$ represents the similarity measure of data points x_i and y_j.

After ensuring that the multimodal expressions are consistent at the same time point, the data is cleaned and standardized to a uniform resolution. Then the multimodal data is fused to obtain a more comprehensive expression.

This paper adopts feature-level fusion, that is, the data is processed by extracting the feature vectors of each modality and performing weighted fusion. By assigning higher weights to more important features, you can ensure that these features have a greater influence on the model' s predictions, thereby improving the accuracy of the overall prediction.

Weighted fusion formula:

$$F_{\text{fusion}} = \alpha F_{\text{vision}} + \beta F_{\text{hearing}} + \lambda F_{\text{language}} + \delta F_{\text{action}} + \mu F_{\text{physiology}} \tag{4}$$

In Equation (4), F_{vision} is the feature of the visual modality, F_{hearing} is the feature of the auditory modality, F_{language} is the feature of the language modality, F_{action} is the feature of the action modality, and $F_{\text{physiology}}$ is the feature of the physiological modality. α, β, λ, δ, μ are the weight coefficients, which satisfies $\alpha + \beta + \lambda + \delta + \mu = 1$.

3. AI analysis module

Artificial intelligence, through its powerful computing and learning capabilities, can quickly identify potential patterns and relationships in a big data environment and automatically process complex data sets. Through machine learning algorithms, AI can extract features from historical data, learn and build predictive models, and provide a scientific basis for the decision-making process.

3.1. Action analysis module

This module is mainly used to extract key actions and action sequence features in ICH performances, thereby achieving behavior classification and pattern extraction. In order to achieve the above functions, the key points of the action are first described.

Assume that in a certain frame of image, the key point position of the human body is $P = \{p_1, p_2, \ldots\ldots, p_n\}$, where p_i is the two-dimensional coordinate of the i-th joint point.

The key point detection formula for a certain frame is:

$$P(t) = \{(x_1, y_1), (x_2, y_2), \ldots\ldots, (x_n, y_n)\} \tag{5}$$

(x_i, y_i) in Equation (5) represents the two-dimensional coordinates of the i-th joint point.

Then, the long short-term memory network (LSTM) is used to capture the temporal characteristics of the action represented by the trajectory of the key points [34,35].

In the process of action recognition, LSTM can help understand the long-term and short-term dependencies of actions.

LSTM captures long-term dependencies through its special memory unit structure. Its core is to dynamically adjust the flow of information through multiple gating mechanisms (forget gate, input gate, and output gate), thereby performing well in processing action points.

In LSTM, the forget gate is used to decide how much memory from the previous moment is discarded, the input gate is used to decide how much current input information is added to the memory cell, and the output gate is used to decide how much information is extracted from the memory cell as the output at the current moment.

The data flow in LSTM is shown in **Figure 1**.

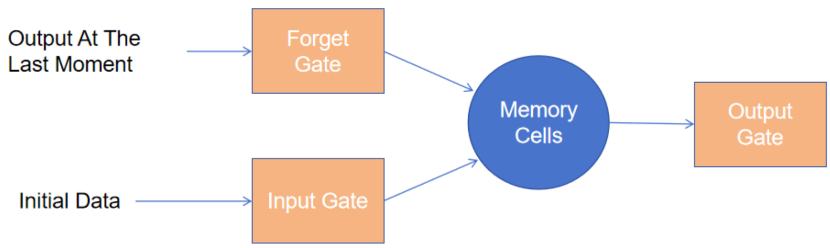

Figure 1. Data flow diagram.

The memory cells are determined by the forget gate and the input gate to ensure that useful information can be selectively retained and prevent premature loss of information.

Finally, the Convolutional Neural Networks (CNN) is used to classify the extracted action features and identify the specific action type [36].

CNN automatically extract features from data through multiple levels of operations. First, the convolution layer extracts local features by sliding the convolution kernel, the activation layer performs nonlinear transformations on the convolution results, and the pooling layer further reduces the dimension and reduces the amount of calculation. Then, the fully connected layer integrates the extracted features and outputs the final prediction results. The whole process is trained through the back propagation algorithm to optimize the network parameters.

CNN action recognition formula:

$$\tilde{y} = Soft\,max(W \times CNN(X) + b) \quad (6)$$

$\tilde{y}$ in Equation (6) represents the predicted action category, *W* and *b* are weights and biases, and *CNN*(*X*) is the feature extraction of the input data through the CNN network.

3.2. Audio analysis module

Audio signals can be used to extract relevant features in a variety of ways. The method used in this paper is the Mel-Frequency Cepstral Coefficients (MFCC) method to extract audio features. This method can transform audio signals into features that reflect human hearing characteristics.

MFCC formula:

$$\text{MFCC} = DC''T(log(\,|FFT(x(t))|)) \quad (7)$$

In Equation (7), *FFT*(*x*(*t*)) is the spectrum obtained by fast Fourier transform of the audio signal, and $DC^{''}T$ is discrete cosine transform, which is used to convert spectrum data into frequency features.

The support vector machine (SVM) algorithm is used for audio classification. It maximizes the interval to find a segmentation hyperplane, so that the audio features of different emotions can be distinguished.

SVM formula:

$$argmin_{w,b}\frac{1}{2}||w||^2 \quad (8)$$

In Equation (8), w is the normal vector of the hyperplane, and b is the bias term.

3.3. Semantic analysis module

When performing semantic analysis, each word in the text is first vectorized through the Word2Vec model to capture the semantic information of the word. The relevant formula is:

$$W_t = f(Word2Vec(t)) \quad (9)$$

In Equation (9), W_t is the vectorized representation of the term *t*, and *f* is the output of the Word2Vec model.

Then, important entities in the text are identified, such as names of people, places, or cultural relics. This recognition is achieved using the Named Entity Recognition (NER) method:

$$NER(T) = \{E_1, E_2, E_3, \ldots\ldots, E_m\} \quad (10)$$

Among them, E_1, E_2, E_3, ..., E_m are entities identified from the text *T*, such as “Mei Lanfang” and “Beijing Opera” are identified from a traditional opera text.

Based on the above, sentiment analysis can be performed on the relevant text and the relevant knowledge graph can be established. The sentiment analysis in this paper is based on the LSTM model. For each text, its corresponding sentiment score can be calculated to distinguish different semantics.

Figure 2 is a partial knowledge graph of China’ s ICH, with nodes including cultural heritage items, categories, locations, and inheritors.

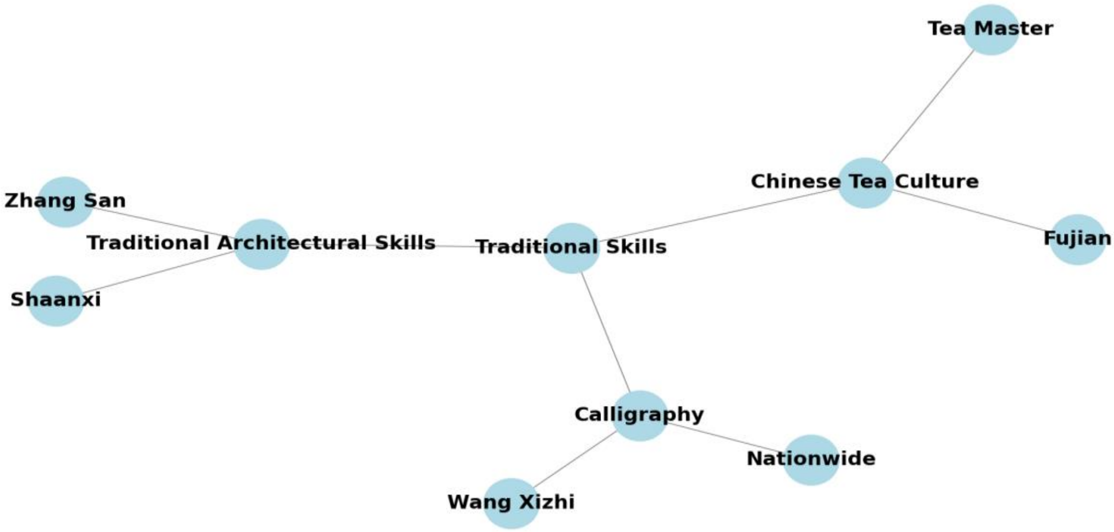

Figure 2. Knowledge graph.

3.4. Image and texture analysis module

Based on the digital preservation and efficient storage of ICH, image processing is particularly important. Image preprocessing is the first step in image analysis, which mainly includes the following operations:

Denoising: This paper uses Gaussian filtering to remove noise from the image to ensure the accuracy of subsequent analysis.

Gaussian filtering formula:

$$G(x,y) = \frac{1}{2\pi\sigma^2} exp(-\frac{x^2+y^2}{2\sigma^2}) \tag{11}$$

In Equation (11), $G(x, y)$ represents the Gaussian filter kernel, σ is the standard deviation, and x, y are the pixel coordinates in the image.

Grayscale: Convert a color image into a gray image for subsequent calculations.

The conversion formula is:

$$I_{gray} = 0.2989 \times I_R(x,y) + 0.5870 \times I_G(x,y) + 0.1140 \times I_B(x,y) \tag{12}$$

$I_R(x,y)$, $I_G(x,y)$, and $I_B(x,y)$ in Equation (12) represent the pixel values of the red, green, and blue channels, respectively.

After preprocessing the image, texture analysis is performed. This paper uses the Gabor wavelet transform method for texture analysis. Gabor wavelet transform is used to extract the frequency and direction characteristics of the image and can effectively capture the texture information in the image. The Gabor filter convolves the image with a set of filters of different scales and directions to extract texture features.

Gabor wavelet transform formula:

$$G(x,y,\lambda,\theta,\psi,\sigma) = exp(-\frac{x^2+y^2}{2\sigma^2}) \times cos(2\pi\frac{x}{\lambda}+\psi) \tag{13}$$

In Equation (13), λ is the wavelength, θ is the direction of the filter, ψ is the phase, and σ is the standard deviation of the Gaussian function.

For image analysis, this paper uses the CNN model for image analysis. It extracts multi-level features of the image through multiple convolutional layers, pooling layers, and fully connected layers, and then trains a deep neural network to classify different cultural heritage images, so that different styles, periods, or categories can be identified.

Image recognition CNN convolutional layer formula:

$$Y_{ij} = \sum_{m} \sum_{n} X_{i+m,j+n} \times K_{m,n} \tag{14}$$

In Equation (14), *X* is the input image, *Y* is the output feature map, and *K* is the convolution kernel.

4. Intelligent interactive recommendation module

4.1. User portrait establishment

This paper can establish a user portrait based on the ICH content that the user has browsed, watched, and listened to, the user’ s preference category, and the user’ s interaction data. Based on the user portrait and multimodal data perception and data analysis, it recommends ICH content that the user may be interested in.

4.2. Intelligent recommendation algorithm model

This paper adopts the user-based collaborative filtering (CF) algorithm when making recommendations [37]. Its idea is to make recommendations based on the behaviors of other users with similar interests to the current user. Its core is to calculate the similarity between users to divide users with similar interests for recommendation. This paper adopts the cosine similarity calculation method.

Cosine similarity calculation:

$$Sim(u,v) = \frac{\sum_{i=1}^{n} R_{ui} \cdot R_{vi}}{\sqrt{\sum_{i=1}^{n} R^2{}_{ui}} \times \sqrt{\sum_{i=1}^{n} R^2{}_{vi}}} \tag{15}$$

In Equation (15), R_{ui} and R_{vi} respectively represent the ratings of user *u* and *v* on content *i*.

In actual use, real-time feedback from users is very important. Based on multimodal biosensing functions, this paper can analyze the user’ s emotional feedback on a certain ICH content based on the user’ s real-time feedback data, such as clicks, dwell time or emotional response, in actual use, so as to dynamically adjust the interest preference recommendation.

4.3. User interface display

Figure 3 shows the user interface diagram of the system. In addition to the display area showing the style of ICH, the user interface also has a search function, a friend function, a word cloud function, a browsing review function, and a one-click recommendation function. Clicking the search function button allows users to search for the ICH they are interested in. Clicking the friend function allows users to view the public information of users who have browsed the same or related ICH content as themselves, as well as the ICH content recommended by the user. The clickable word cloud function can obtain a personalized ICH recommendation word cloud. Clicking the browsing history can find the ICH content that the user has browsed. The clickable one-click recommendation can add the ICH content being displayed to the user' s personal recommendation, so that the ICH content can be spread in this way.

Figure 3. User interface diagram.

5. Result display

5.1. ICH storage

Figure 4 shows the distribution of the number of ICH categories stored in the system through the system' s multimodal perception function. The horizontal axis represents the specific number, and the vertical axis represents the category of ICH items. The ICH stored in the system mainly includes four categories: traditional dance, traditional handicrafts, traditional music, and opera. Each major category is divided into multiple subcategories. For example, traditional dance is divided into folk dance and court dance, traditional music is divided into folk music and court music, traditional handicrafts are divided into brocade, wood carving and pottery, and opera is divided into Peking opera and other local operas. Different categories of ICH content are also stored in the system in different forms and can be displayed in different forms. The total number of ICH content in four major categories and multiple subcategories stored in the system exceeds 100,000.

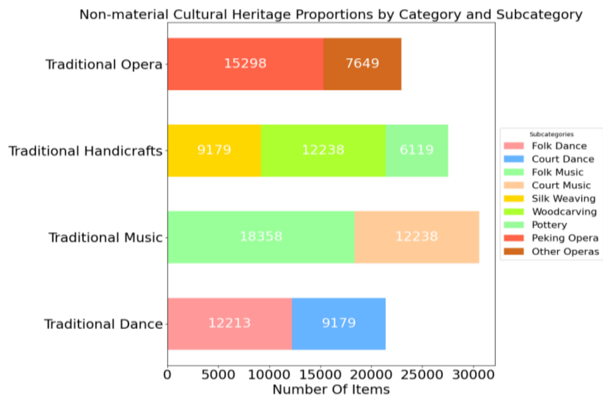

Figure 4. ICH storage distribution diagram.

5.2. Interactive tag cloud

Figure 5 shows the interactive tag cloud of intelligent recommendation. The tags contain the entries of traditional ICH, including the project name, region, inheritor and other information of ICH. Every user who has just entered the system can click the word cloud function button in the user interface to select one or more entries according to their interests to directly query the relevant ICH content. The design of the interactive tag cloud demonstrates the system' s storage capacity, which can store and display the perceived ICH content. At the same time, the design of the interactive tag cloud not only gives the system the opportunity to understand the user' s interests for the first time, which is conducive to subsequent intelligent recommendations, but also gives users the power to make their own choices. In the subsequent use of the system, users can use this function to continuously update their tag cloud content and gain a deeper understanding of the ICH they are interested in. The in-depth update of the tag cloud content also represents the user' s in-depth understanding of the ICH.

Figure 5. Interactive tag cloud.

5.3. Recommendation effect

Figure 6 shows the specific process and effect of a recommendation. The numbers in the figure represent the number of candidates sets at different stages, and the vertical axis represents the name of each stage, that is, the different steps in the recommendation process. In the initial stage of this recommendation process, there were a total of 1000 relevant ICH data items. After screening in the data preprocessing stage, 826 relevant ICH data items remained. After the collaborative filtering algorithm, 510 relevant ICH data items remained. After these data items were sorted by relevance, 274 relevant ICH data items were finally recommended to users, and users finally recommended 232 ICH contents. The probability represents the percentage of the next layer of ICH data items in the previous layer. Among them, the proportion of data items left after preliminary screening is 82.60%, the proportion of data items left after collaborative filtering is 61.74% of the previous layer, and the proportion of data items left after relevance sorting is 53.73%. It can be seen that the system in this paper strictly screened the results during the recommendation, and the correlation was high and the recommendation was accurate. After the recommendation was made to the user, the probability that the user would click on the recommendation was 84.67%.

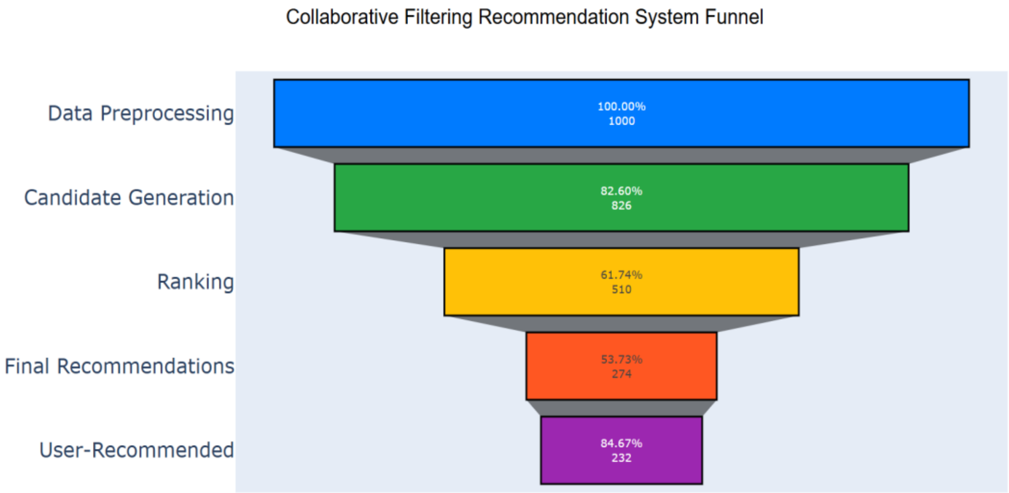

Figure 6. Recommendation flowchart.

Figure 7 is a graph of recommendation precision changes with ranking top k drawn based on all user one-click recommendation click data, where k means selecting the first k items in the ranking list to recommend to the user in a recommendation process. The horizontal axis represents the change of k value, and the vertical axis describes the change of overall precision. The calculation method of overall precision is to calculate the weighted average of the recommendation precision of all ICH types, and the weight is determined by the distribution ratio of ICH types in the system. When the k value is small, the overall recommendation precision of the system is close to 1. When the k value increases, the overall precision tends to decrease. When the k value increases to 200, the overall precision is 85%. It can be seen that when the system recommends 200 related ICH contents to users at one time, about 170 of them can still be recommended by users, and the recommendation performance of this system is good.

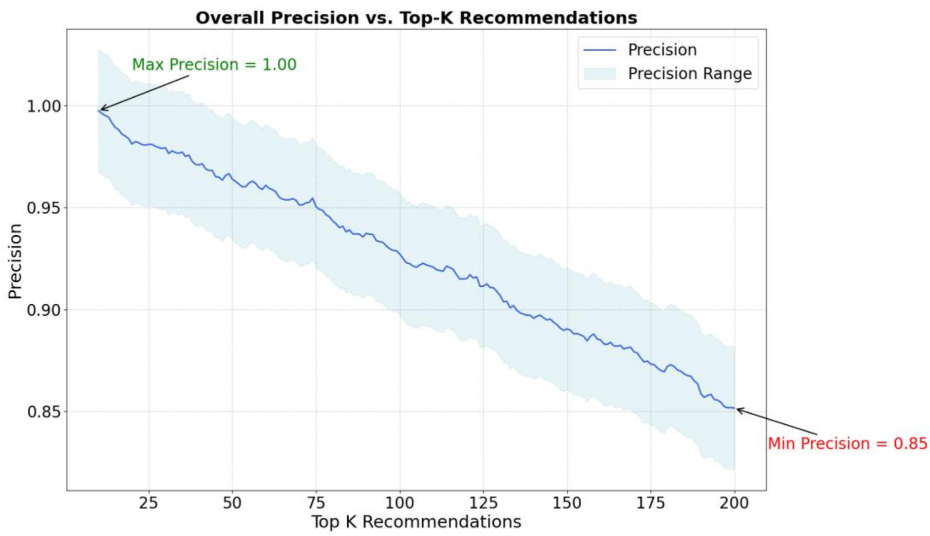

Figure 7. Recommendation precision changes with ranking top k.

5.4. Communication effect

Figure 8 is a geographical heat map drawn based on the geographical distribution of Chinese ICH content recommended by users. The scope of dissemination is the main cities in major countries in Asia. The depth of the heat color represents the dissemination intensity of the current region, which is mainly determined by the total number of shares in the region. The lines represent the dissemination paths between different regions. The dissemination intensity of ICH in China is wider than that in other parts of Asia, which means that the acceptance and dissemination of ICH in China is higher than that in other countries. However, according to the analysis of the dissemination route, China' s ICH has begun to spread in other countries. This shows that the system studied in this paper has strong dissemination capabilities, which is not only an external display of China' s ICH, but also lays the foundation for cultural exchange and cultural innovation.

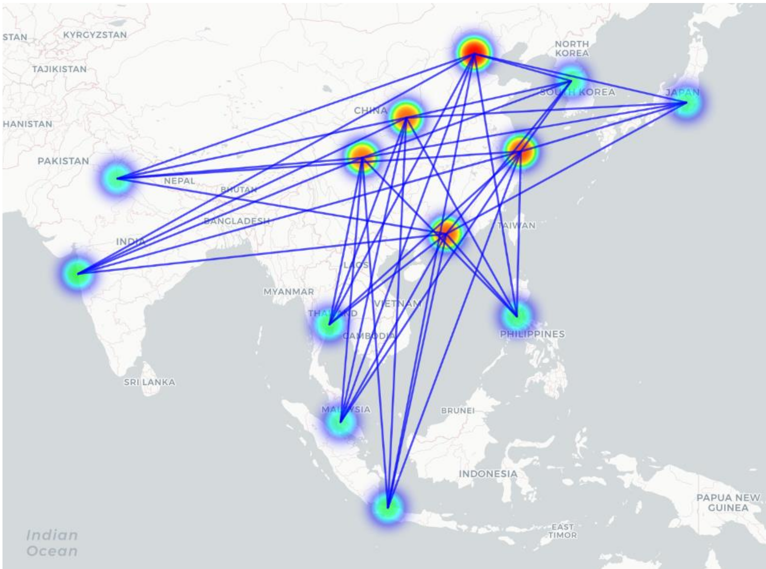

Figure 8. Geographical heat map of ICH.

5.5. User stay time analysis

Table 2 analyzes the stay time of 2000 users. 23.1% of these 2000 users stay for 0–3 min, 28.6% stay for 3–30 min, 32.9% stay for 10–30 min, and 15.4% stay for more than 30 min. This shows that the content and functions of the system are relatively attractive to users and can maintain a certain level of activity. However, there are also a considerable number of users with a short stay time. The user experience needs to be further improved to retain these users. In addition, attention should be paid to the needs of users with a longer stay time to maintain their activity.

Table 2. User stay time analysis table.

Stay time interval	Number of users	Percentage (%)
0–3 min	462	23.1%
3–10 min	572	28.6%
10–30 min	658	32.9%
More than 30 min	308	15.4%

6. Conclusions

This paper introduces AI technology and bio-perception technology to design a new ICH resource construction system. The system is mainly composed of three modules: multimodal bio-perception module, AI analysis module and intelligent interactive recommendation module. In the multimodal bio-perception module, different acquisition devices are used to realize data extraction, storage and preliminary data processing of ICH content of different modalities. In the AI analysis module, the movements, audio, text and even textures and images of different types of ICH content are further processed and analyzed. Different types of ICH content are stored in the system in different forms. A unique interactive tag cloud is designed in the intelligent interactive recommendation module to facilitate users' screening of ICH of interest, and provide personalized intelligent ICH recommendations for different users. Through data analysis, it is found that this study has made certain contributions to the storage and reproduction, protection and dissemination of ICH, and also provides a new reference for the protection of ICH. However, the research in this paper also has certain limitations. There are still certain problems at the technical level in connecting ICH content to different regions, and the dissemination scope of ICH is not wide enough. Therefore, the future research direction is to better realize the interconnection of ICH content in different regions by solving technical problems, and how to enhance the breadth of dissemination of ICH.

Funding: This research was funded by Research project achievements of Zhejiang Federation of Humanities and Social Sciences, project number: 2025B047.

Ethical approval: Not applicable.

Conflict of interest: The author declares no conflict of interest.

References

1. Hou, Yumeng, Kenderdine, Sarah, Picca, Davide, Egloff, Mattia, Adamou, Alessandro." Digitizing intangible cultural heritage embodied: State of the art." Journal on Computing and Cultural Heritage (JOCCH) 15.3 (2022): 1-20.
2. Eichler, Jessika. "Intangible cultural heritage, inequalities and participation: who decides on heritage?." The International Journal of Human Rights 25.5 (2021): 793-814.
3. Chen, Zhaoyu. "Visualizing experiencescape–from the art of intangible cultural heritage." Current Issues in Tourism 25.4 (2022): 559-578.
4. Spiteri, Marthese, and Shu-Nu Chang Rundgren. "Literature review on the factors affecting primary teachers' use of digital technology." Technology, Knowledge and Learning 25.1 (2020): 115-128.
5. Skare, Marinko, and Domingo Riberio Soriano. "How globalization is changing digital technology adoption: An international perspective." Journal of Innovation & Knowledge 6.4 (2021): 222-233.
6. Vargo, Deedra, Zhu, Lin, BenWell, Briana, Yan, Zheng. "Digital technology use during COVID-19 pandemic: A rapid review." Human Behavior and Emerging Technologies 3.1 (2021): 13-24.
7. Abich IV, Julian, Parker, Jason, Murphy, Jennifer S., Eudy, Morgan. "A review of the evidence for training effectiveness with virtual reality technology." Virtual Reality 25.4 (2021): 919-933.
8. Bottani, Eleonora, and Giuseppe Vignali. "Augmented reality technology in the manufacturing industry: A review of the last decade." Iise Transactions 51.3 (2019): 284-310.
9. Chen, Yulong, and Ke Xue. "Interactive Design of Intangible Cultural Heritage Based on Social Sharing—The Digital Revitalization of Su Embroidery." Academic Journal of Humanities & Social Sciences 4.4 (2021): 53-60.
10. Lo, Patrick, Chan, Holly H.Y., Tang, Angel W.M., Chiu, Dickson K.W., Cho, Allan, See-to, Eric W.K.,. et al "Visualising and

revitalising traditional Chinese martial arts: visitors' engagement and learning experience at the 300 years of Hakka Kungfu." Library Hi Tech 37.2 (2019): 269-288.
11. Damala, Areti, Ian Ruthven, and Eva Hornecker. "The MUSETECH model: A comprehensive evaluation framework for museum technology." Journal on Computing and Cultural Heritage (JOCCH) 12.1 (2019): 1-22.
12. Nikolakopoulou,Vasiliki,Printezis,Petros,Maniatis,Vassilis,Kontizas,Dimitris,Vosinakis,Spyros,Chatzigrigoriou,Pavlos,et al. "Conveying intangible cultural heritage in museums with interactive storytelling and projection mapping: the case of the mastic villages." Heritage 5.2 (2022): 1024-1049.
13. Buyuksalih, Gurcan, Kan, Tuna, Ozkan, Gozde Enc, Meric, Muge, Isın, Lale, Kersten Thomas P. "Preserving the knowledge of the past through virtual visits: From 3D laser scanning to virtual reality visualisation at the Istanbul Çatalca Incegiz caves." PFG–Journal of Photogrammetry, Remote Sensing and Geoinformation Science 88.2 (2020): 133-146.
14. Trunfio, Mariapina, Lucia, Maria Della, Campana, Salvatore, Magnelli, Adele." Innovating the cultural heritage museum service model through virtual reality and augmented reality: The effects on the overall visitor experience and satisfaction." Journal of Heritage Tourism 17.1 (2022): 1-19.
15. Karuzaki, Effie, Partarakis,Nikolaos,Patsiouras,Nikolaos,Zidiannakis,Emmanouil,Katzourakis,Antonios,Pattakos,Antreas,et al. "Realistic virtual humans for cultural heritage applications." Heritage 4.4 (2021): 4148-4171.
16. Jiang, Shan, Moyle, Brent, Yung, Ryan, Tao, Li, Scott, Noel. "Augmented reality and the enhancement of memorable tourism experiences at heritage sites." Current Issues in Tourism 26.2 (2023): 242-257.
17. Banfi, Fabrizio, Raffaella Brumana, and Chiara Stanga. "Extended reality and informative models for the architectural heritage: from scan-to-BIM process to virtual and augmented reality." Virtual Archaeology Review 10.21 (2019): 14-30.
18. Xu, Wulong. "Research on the Communication Opportunities of Intangible Cultural Heritage under the Background of Big Data and AI." Journal of Artificial Intelligence Practice 6.8 (2023): 12-17.
19. Yue, Man, Guan Wang, and Zheng Li. "The Digital Protection and Inheritance of Intangible Cultural Heritage:--Taking the Qing Dynasty horse-face skirt as an Example." Highlights in Art and Design 1.3 (2022): 83-87.
20. Di Giulio, Roberto, Boeri, Andrea, Longo, Danila, Gianfrate, Valentina, Boulanger, Saveria O.M., et al. "ICTs for accessing, understanding and safeguarding cultural heritage: the experience of INCEPTION and ROCK H2020 projects." International Journal of Architectural Heritage 15.6 (2021): 825-843.
21. Stapleton, Larry,O' Neill,Brenda,Cronin,Kieran,Mcinerney,Patrick,Hendrick,Matthew,Dalton,Eoin. "A semi-automated systems architecture for cultural heritage: sustainable solutions for Digitising cultural heritage." IFAC-PapersOnLine 52.25 (2019): 562-567.
22. Tian, Jin, Cao, YiFan, Feng, LingYi, Fu, Dong Ting, Yuan, Lin Ping, Qu, Hu Min, et al. "Poeticar: Reviving traditional poetry of the heritage site of jichang garden via augmented reality." International Journal of Human–Computer Interaction 40.6 (2024): 1438-1454.
23. Xu, Liang, Lu Lu, and Minglu Liu. "Construction and application of a knowledge graph-based question answering system for Nanjing Yunjin digital resources." Heritage Science 11.1 (2023): 1-17.
24. Munster, Sander, Maiwald, Ferdinand, Lenardo, Isabella di, Henriksson, Juha, Isaac, Antoine, Fraf, Manuela Milica, et al. "Artificial Intelligence for Digital Heritage Innovation: Setting up a R&D Agenda for Europe." Heritage 7.2 (2024): 794-816.
25. Yin, Jie. "Application of Intelligent Image Recognition and Digital Media Art in the Inheritance of Black Pottery Intangible Cultural Heritage." ACM Transactions on Asian and Low-Resource Language Information Processing 23.6 (2024): 1-15.
26. Li, Meng, Yun Wang, and Ying-Qing Xu. "Computing for Chinese cultural heritage." Visual Informatics 6.1 (2022): 1-13.
27. Deng, Meizhen, Yi meng Liu, and Ling Chen. "AI-driven innovation in ethnic clothing design: an intersection of machine learning and cultural heritage." Electronic Research Archive 31.9 (2023): 5793-5814.
28. Mintz, Yoav, and Ronit Brodie. "Introduction to artificial intelligence in medicine." Minimally Invasive Therapy & Allied Technologies 28.2 (2019): 73-81.
29. Kaul, Vivek, Sarah Enslin, and Seth A. Gross. "History of artificial intelligence in medicine." Gastrointestinal endoscopy 92.4 (2020): 807-812.
30. Gunning, David, and David Aha. "DARPA' s explainable artificial intelligence (XAI) program." AI magazine 40.2 (2019): 44-58.
31. Li, Yi, Li, Shi Yuan, Wang, Jin, Liu, Guo Zhen. "CRISPR/Cas systems towards next-generation biosensing." Trends in biotechnology 37.7 (2019): 730-743.

32. Moin, Ali,Zhou,Andy,Rahimi,Abbas,Menon,Alisha,Benatti,Simone,Alexandrow,George, et al. “A wearable biosensing system with in-sensor adaptive machine learning for hand gesture recognition.” Nature Electronics 4.1 (2021): 54-63.
33. Deriso, Dave, and Stephen Boyd. “A general optimization framework for dynamic time warping.” Optimization and Engineering 24.2 (2023): 1411-1432.
34. Van Houdt, Greg, Carlos Mosquera, and Gonzalo Napoles. “A review on the long short-term memory model.” Artificial Intelligence Review 53.8 (2020): 5929-5955.
35. Hua, YuXiu,Zhao,ZhiFeng,Li,RongPeng,Chen,XianFu,Liu,ZhiMing,Zhang,HongGang. “Deep learning with long short-term memory for time series prediction.” IEEE Communications Magazine 57.6 (2019): 114-119.
36. Li, Ze wen, LIu, Fan, Yang, Wen Jie, Peng, Shou Heng, Zhou, Jun. “A survey of convolutional neural networks: analysis, applications, and prospects.” IEEE transactions on neural networks and learning systems 33.12 (2021): 6999-7019.
37. Wu, Le, He, Xiang Nan, Wang, Xiang, Zhang, Kun, Wang, Meng. “A survey on accuracy-oriented neural recommendation: From collaborative filtering to information-rich recommendation.” IEEE Transactions on Knowledge and Data Engineering 35.5 (2022): 4425-4445.