International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18 (2026) pp. 1-18

Article

Research on the Algorithmic Interpretation and Dissemination Mechanism of World Heritage Values from the Perspective of Digital Humanities

Shangqian Wu[1] and Suresh Narayanen[1,*]

[1] Senior Lecturer, Centre for Global Archaeological Research, Universiti Sains Malaysia, 11800 USM, Pulau Pinang, Malaysia
* Correspondence author: sureshnarayanen@usm.my

Abstract: World heritage value is the core of heritage protection and inheritance, and how to communicate the value of world heritage effectively is a major issue in the current world heritage protection and inheritance. Based on the perspective of interpretation and creation of world heritage value, this study constructs a world heritage value co-creation model based on blockchain PBFT algorithm, and designs a Dunhuang cultural heritage intelligent data resource management system based on this model. Meanwhile, using structural equation modeling, the influencing factors of world heritage digital communication are explored, and the design of world heritage digital communication mechanism is realized. It is shown that the ML-PBFT algorithm proposed in this paper outperforms the standard PBFT algorithm in terms of transaction delay, throughput and communication overhead. Compared with the traditional centralized crowdsourcing system, the system in this paper has obvious advantages in crowdsourcing matching, task result auditing and crowdsourcing data authorization sharing. In addition, the characteristics of the digital communication media of intangible cultur heritage and the audience perception factors can significantly and positively influence the audience's behavioral willingness, and the user's perception plays a partly mediating role in this study.

Keywords: world heritage; blockchain; PBFT algorithm; structural equation modeling; digital dissemination mechanism; intangible cultur heritage

1. Introduction

World heritage refers to sites and practices of outstanding cultural, historical, artistic, architectural, scientific, and social significance on a global scale [1-2]. These heritages not only embody the civilizational achievements of different historical periods, but also hold profound value that deeply influences today's social and cultural development [3-4]. At present, the interpretation and dissemination of heritage values still predominantly rely on the expert discourse system. With the rise of the digital era, this traditional mode faces numerous challenges; in this context, algorithmic interpretation has emerged.

Algorithmic interpretation draws on digital humanities methods to mine and analyze heritage data using technologies such as natural language processing and semantic segmentation, revealing value dimensions that are otherwise difficult to capture [5-7]. Digital humanities is an interdisciplinary field at the intersection of modern information technology and the humanities, aiming to transform the ways knowledge is acquired, annotated, compared, sampled, interpreted, and presented [8-10]. It provides new approaches and tools for organizing, managing, and disseminating world heritage values. The essence of digital humanities lies in methodological shifts that enable the granularization of knowledge units, semantic organization of knowledge, and visualization of knowledge presentation [11-13]. This vision supports the in-depth description of world heritage value and the orderly organization of heritage information. Leveraging technologies such as mapping, virtual reality, and 3D modeling, a range of applications—such as virtual museums and digital reconstructions—have emerged. Such digital communication not only transcends spatial and temporal limitations to reach wider audiences, but also innovates ways of recording and displaying heritage [14-17]. Therefore, exploring the algorithmic interpretation and dissemination mechanism of world heritage value is of great significance for the creative transformation and innovative development of cultural heritage.

This study investigates the algorithmic interpretation and dissemination mechanism of world heritage value from a digital humanities perspective. For algorithmic interpretation, a blockchain-based world heritage value co-creation model is first constructed, then a multi-level PBFT (ML-PBFT) algorithm is developed and its performance analyzed; subsequently, a Dunhuang cultural heritage smart data resource management system built on this model is tested for performance and security. Regarding digital dissemination, the study constructs a model of influencing factors based on SOR theory, tests the model hypotheses, and, on that basis, innovatively designs a digital dissemination mechanism for world heritage.

2. Interpretation and Creation of Values of the World Cultural Heritage

With the growing emphasis on the "revitalization" of cultural heritage, the advancement of digital technologies, and the rise of digital humanities, interdisciplinary research increasingly focuses on the deep excavation and creation of cultural heritage value.

Smart data is a high-level organizational form of data resources. Cultural heritage smart data is condensed from vast amounts of heritage data, and its potential value can be extracted and presented through algorithms, visualization, and other technologies. The value of cultural heritage smart data is is gradually created in the process of resource construction and service application. Value creation, in essence, is the interpretation of the potential value latent within the data.

This chapter analyzes the logic of value creation of world cultural heritage smart data first clarifying the core elements of value creation and then examining the four links: value activation, value aggregation, value mining, and value release.

2.1. Core Elements of Cultural Heritage Intelligent Data Value Creation

The core elements of smart data value creation of world cultural heritage include participating subjects, data resources, data standards and supporting technologies. The synergistic relationship and resource integration mechanism among the subjects are shown in Figure 1. Through the unification data standards and exchange of technical services, the multiple subjects can realize the integration of data resources and the construction and service of intelligent data resources, and promote the creation of smart data value.

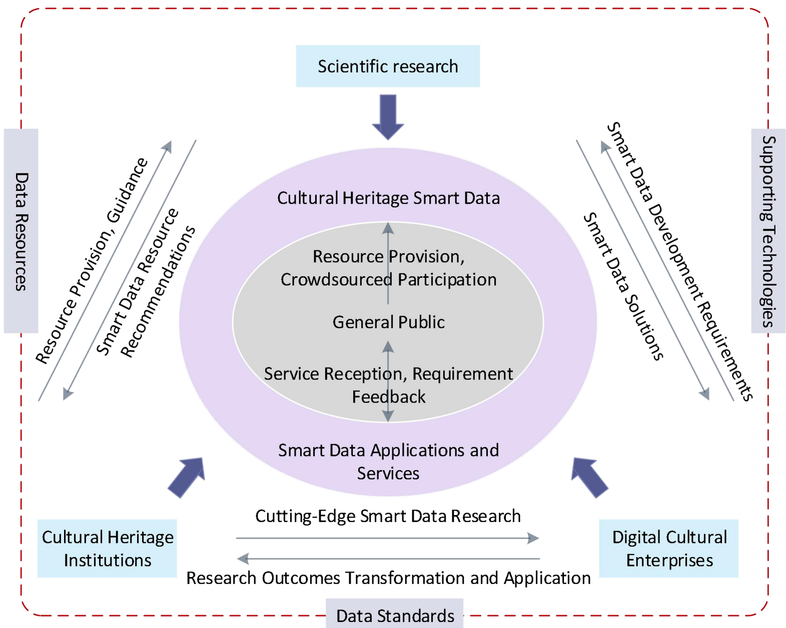


Figure 1. The subject synergy relationship and resource integration mechanism

2.2. Cultural Heritage Intelligent Data Value Creation Segments

The logic of smart data value creation in the world cultural heritage is shown in Figure 2. Under the synergistic cooperation of the participating subjects, cultural heritage data resources are collected, processed, described and organized through consistent data standards, and the smart data are released by using technologies such as data mining, artificial intelligence, virtual reality, digital twin, etc. to provide scenario-based applications and services. Taking the data processing process as the main vein, cultural heritage smart data has gone through four value creation processes, namely, value activation, aggregation, mining and release, in the process of digitization, datatization, smartification and scenarioization.

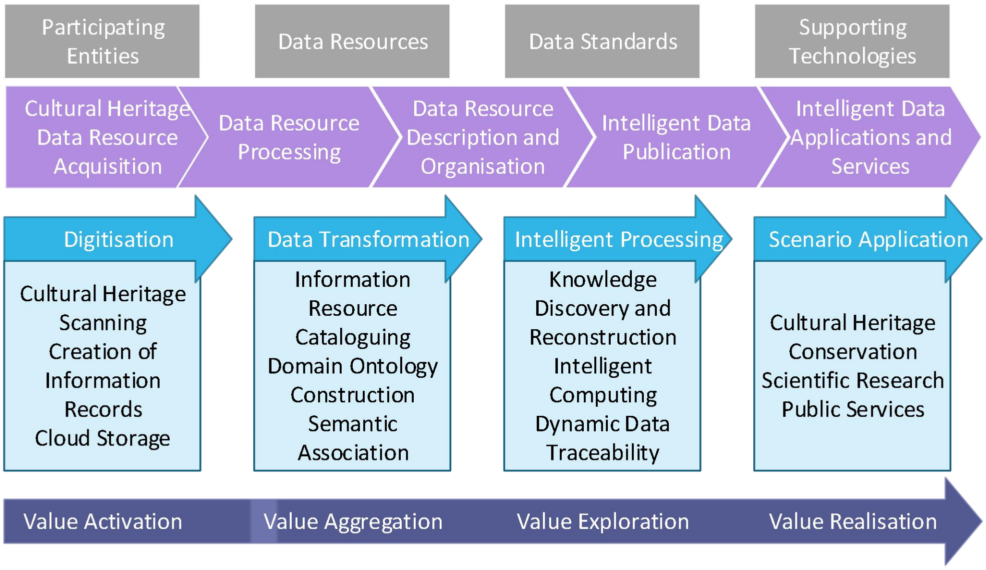


Figure 2. The logic of value creation of World Cultural Heritage smart data

3. Blockchain-based world heritage value co-creation model construction

Drawing on the logic of value creation of world cultural heritage smart data, this chapter integrates blockchain technology and related algorithms to construct a world cultural heritage value co-creation model, thereby realizing algorithmic interpretation of world heritage value.

3.1. Blockchain technology

The blockchain is mainly composed of three parts, namely, the genesis block, the main chain and the data block. The main chain is a trusted and independent blockchain network formed by connecting time-stamped data blocks in a chain structure. The genesis block is the first block in the blockchain and is the source of the blockchain. Data blocks are blocks that specifically encapsulate data, and each data block contains the cryptographic hash, timestamp, and transaction data of the previous data block.

The characteristics of the technical elements of blockchain and its main applications in the value co-creation of world cultural heritage are as follows:

(1) Distributed Ledger Technology

Distributed ledger technology is one of the core technologies of blockchain, which is a database technology that is shared, replicated and synchronized among network members, and adopts P2P distributed network topology for distributed bookkeeping: P2P is a peer-to-peer, peer-to-peer network system without a central server, relying on user nodes within the network to exchange information. Therefore, distributed ledger technology can guarantee the authenticity and reliability of the uploading and publishing of cultural heritage smart data resources by each user node in the blockchain network platform, as well as the fairness of obtaining the corresponding certificates and virtual coins, and paying virtual coins for trading cultural heritage smart data resources.

(2) Asymmetric Encryption Algorithm

The blockchain adopts asymmetric encryption algorithm, i.e., encryption and decryption adopt encryption algorithms with different keys to generate public key, private key and ciphertext of each user block in the chain. The public key is open to each user node within the network, which guarantees the openness and transparency of the transaction information of cultural heritage smart data resources within the network and realizes the mutual trust between the two parties to the transaction. The private key, on the other hand, is privately owned by each user node within the platform to provide security for the detailed data and user privacy information of cultural heritage smart data resource transactions within the platform.

(3) Consensus Mechanism

Consensus mechanism is a strategy and method for each node in the blockchain to reach agreement. Currently, the main consensus algorithms used in blockchain are proof-of-work (Pow), proof-of-equity (Pos), proof-of-delegated-equity (Dpos), and practical Byzantine fault-tolerant (PBFT) consensus mechanism based on voting. Based on the special needs of determinism and throughput rate, this paper adopts the vote-based PBFT consensus protocol.

To improve the performance of the PBFT algorithm, this paper introduces a multi-level theory, where each level corresponds to a different node group. The node group can be represented as $L_0, L_1, L_2, \ldots, L_k$, where L_0 is the node group at the highest level, L_k is the node group at the lowest level, and each node group contains a set of backup nodes with different roles. The flow of the improved PBFT algorithm is as follows:

1) Node group division. The nodes are divided into several node groups of different levels, each level contains a certain number of nodes, which can be expressed as $L_0, L_1, L_2, \ldots, L_k$, each node group L_i contains N_i nodes.

2) Hierarchical view. For each node group L_i, a hierarchical view is introduced to represent the consensus view of that node group. The hierarchical view consists of view number v_i, sequence number n_i, and hash value H_i.

3) Multi-level pre-preparation and preparation. In multilevel PBFT, each node group L_i is responsible for performing the pre-preparation and preparation phases. Each node group L_i generates pre-preparation messages and preparation messages for the hierarchical view.

4) Hierarchical Submission and Response. Each node group L_i generates hierarchical submission message and hierarchical reply message.

5) Hierarchical View Transformation. In multilevel PBFT, hierarchical view switching can be triggered by the master node L_0, which L_0 broadcasts a view switching message to the other node groups, which coordinate to perform view switching based on this message.

6) Multi-level consensus decision making. Multi-level PBFT implements consensus decision making by aggregating the hierarchical submission messages from each node group, and the decision is accepted only if the majority of the node groups are in agreement.

The blockchain network platform, on the one hand, can use the improved multi-level PBFT consensus mechanism to maintain the real-time synchronization of the data within the chain by each user node, so as to guarantee that the digital educational resources can quickly reach a transaction among the nodes. On the other hand, the voting function of the consensus mechanism can be utilized to realize the audit and authentication of cultural heritage smart data resources, and to carry out the superiority and inferiority of cultural heritage smart data resources uploaded into the blockchain.

(4) Time Stamp

Each block within the blockchain consists of a block header and a block body, in which the block header contains important information such as the timestamp of the block, the hash value of the parent block, and the Merkle root. In blockchain, timestamp is used to record the time information of this block, which is a complete and verifiable proof of time data. The blockchain network platform uses timestamps to record the specific time nodes of uploading, releasing and trading cultural heritage smart data resources by each user node, which facilitates the copyright traceability of cultural heritage smart data resources, and realizes the protection of intellectual property rights within the blockchain network platform, and the proof of trading cultural heritage smart data resources.

(5) Smart Contract

Smart contract refers to "a set of commitments defined in digital form", i.e. digital contract, which can realize the storage, transmission, control and management of value. Using smart contracts, combined with virtual coins in the chain, the blockchain network platform can realize credible transactions without a third party in the chain, promote the effective flow of cultural heritage smart data resources, and realize a high degree of autonomy in the transactions of cultural heritage smart data resources in the blockchain network platform, which reduces the transaction cost of cultural heritage smart data resources and at the same time guarantees the creditworthiness of the transactions.

3.2. Cultural Heritage Intelligence Data Resource Value Co-Creation Model

This paper constructs a value co-creation model of world cultural heritage smart data resources integrating blockchain technology under the knowledge crowdsourcing mode, and the hierarchical structure of the model is shown in Figure 3. The model takes the platform as the medium, the sender pays the fee to obtain the cultural heritage smart data resources to meet the demand, the receiver completes the knowledge task and gets the corresponding contribution reward, and the cultural heritage smart data resources as the cause and the result link each main element, and finally they co-create, transmit and diffuse the value connotation of the cultural heritage.

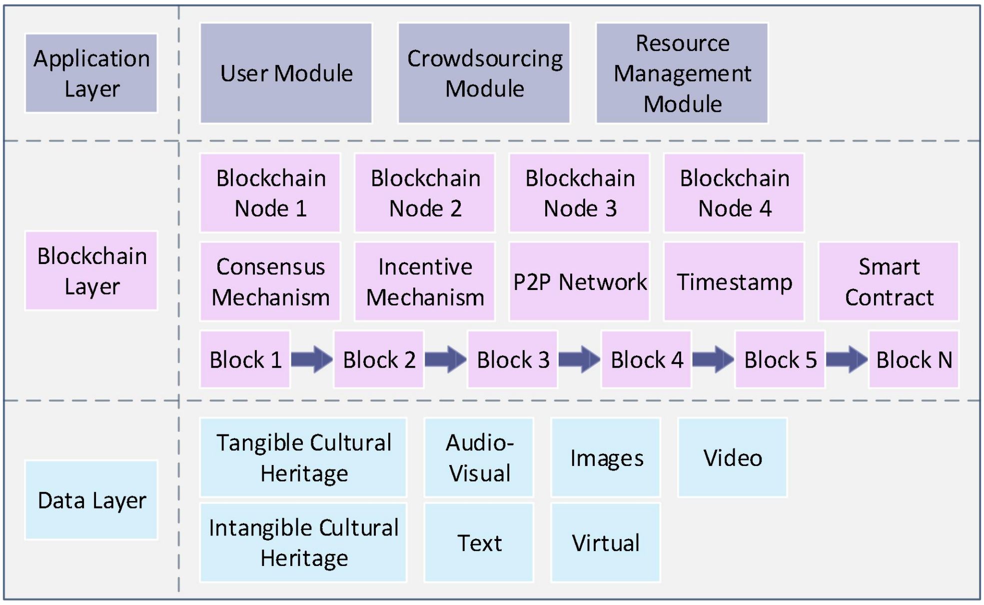


Figure 3. Model hierarchy architecture

3.3. System design based on the value co-creation model

In this section, we take the collection of Dunhuang cultural heritage smart data resources as a knowledge crowdsourcing task, carry out research on the value co-creation of Dunhuang cultural heritage smart data resources, and develop a cultural heritage smart data resource management system deployed in blockchain network as a crowdsourcing platform to verify the effectiveness and feasibility of the model.

(1) Data collection and processing of Dunhuang cultural heritage smart data resources

Data source selection Baidu encyclopedia, Dunhuang Academy official website, Dunhuang Academy social media official account, digital Dunhuang resource base and Dunhuang information resource base, collection of text, images, sound and video, video, virtual animation of digital resources, and will be stored as a permanent link to the resources, link generation can be generated with the help of third-party platforms, the use of github to create a resource library to generate permanent links to the resources to store Dunhuang cultural heritage smart data resources.

(2) System environment configuration

Based on knowledge crowdsourcing of cultural heritage smart data resource management system using Centos, built in Windows11 environment, the front-end framework using vue framework implementation, front-end environment nodejs, back-end framework springboot, back-end environment java jdk1.8, database framework mybatis, database for MySQL, through the smart Contract compilation language Go language using the blockchain part of the development tool idea and blockchain development package hyperledger fabric java sdk for the construction of the blockchain network based on Hyperledger Fabric.

(3) Fabric-based blockchain network construction

After building the SDK with IDEA, the Fabric-based blockchain network will create the channel according to the SDK, get the channel, orderer node, peer node, install the smart contract, instantiate the smart contract, and so on. Blockchain network construction first need to configure the network nodes, and set the number of organizations, the number of organizations will be set to 2, each organization contains 2 nodes, and for these nodes to configure the couchdb state database, set the node's communication certificate mount directory and other configuration information. After the configuration is complete, use the command./byfn.sh to start the entire network, and then use the docker ps command to view the deployed network nodes.

After generating the genesis block, create the network channel channel and add organizations to the channel, then install the chain code, i.e., the smart contract, onto the peer node, instantiate the smart contract, and use the Java SDK to call the smart contract running on the peer node to realize the business call requirements.

(4) System function realization

According to the above system environment configuration and blockchain network construction, realize the cultural heritage intelligent data resource management system based on knowledge crowdsourcing, and upload Dunhuang cultural heritage digital resources to realize the knowledge collection task of cultural heritage digital resources crowdsourcing. The roles of crowdsourcing subjects are divided into three categories: administrators, knowledge contributors, and reviewers, and they enter the system by entering user accounts and passwords.

1) User login and registration module

Newly joined knowledge crowdsourcing participants need to register their identity by selecting their personal role type and entering correct identity details, including user account, password, user name, contact phone number, and address, etc., to complete the identity registration.

2) Knowledge Contributor Module

In the knowledge contributor role, knowledge contributors can click Add, fill in the address link of cultural heritage smart data resources, resource name, resource form, resource profile and other contents, or browse the specific information of the uploaded knowledge contribution in this page, and the knowledge contributors can also carry out the personal information management in this page, which mainly includes the management of personal identity information and so on.

Due to the multimodal and unstructured form of cultural heritage smart data resources, cultural heritage smart data resources are stored in this system as URL links to the original content, and you can directly click the resource hyperlinks to return to the details page of cultural heritage smart data resources. The cultural heritage digital resources are used as knowledge contribution content, which can be submitted after uploading to complete the knowledge task.

3) Auditor Module

The role of knowledge contribution auditor includes information audit management and personal management. Personal management is the browsing and management of the basic information and operation of the auditor. Information audit management means that the knowledge contribution auditor can browse the submitted cultural heritage smart data resources according to the knowledge contribution content submitted by the knowledge contributor, including the address link of the resource, resource name, resource form, resource profile and other contents.

4) Administrator Module

The administrator role includes the main body of the knowledge crowdsourcing contractor and the administrator of the crowdsourcing platform. The administrator can carry out user management, audit process traceability and personal information management. User management is to browse and manage the registered role accounts, user types and user operations of the participants involved in knowledge tasks on the crowdsourcing platform. Audit process traceability means that according to the unique cultural heritage digital resource traceability code generated when a knowledge contributor uploads a knowledge contribution, the operation of the knowledge contribution record can be traced. Personal management is to browse and manage the personal information of administrators.

3.4. Experimental results and analysis

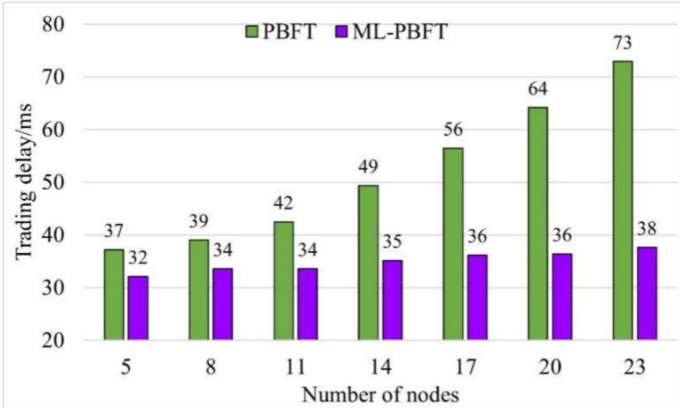
(1) Performance Comparison of Blockchain Consensus Algorithms

A small multi-node blockchain experimental system is implemented based on Java programming language, in which the original PBFT algorithm and the multi-level PBFT algorithm (ML-PBFT) algorithm proposed in this paper are validated. The two algorithms are compared and analyzed in terms of transaction latency, throughput and communication overhead in the presence and absence of Byzantine nodes.

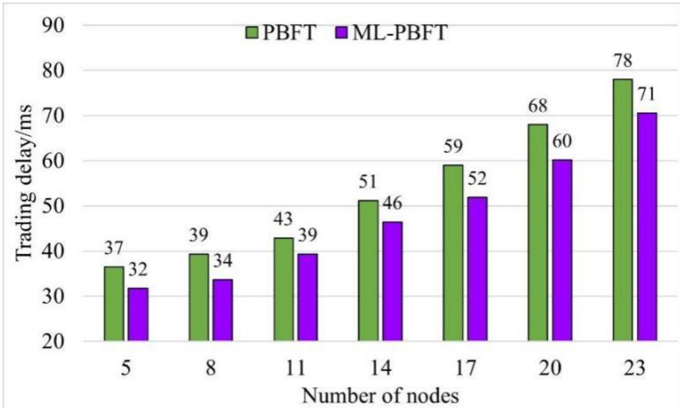
1) Transaction Latency

Transaction delay is the time interval between the client sending a transaction request to the master node and the client confirming the completion of consensus. In order not to lose the generality, the transaction delay is taken as the average value of 300 transactions, and the transaction delay is tested in the case of different number of nodes. A comparison of the transaction latency of the two algorithms is shown in Fig. 4, where (a) and (b) denote the two cases of non-existence of Byzantine nodes and existence of Byzantine nodes, respectively.

From Fig. 4(a), it can be seen that in the absence of Byzantine nodes, the transaction latency of ML-PBFT algorithm is significantly better than that of PBFT algorithm. And with the increase of the number of nodes, the transaction delay of the PBFT algorithm grows faster, while the transaction delay of the ML-PBFT algorithm is more stable and grows slowly. Therefore, in the case of more nodes, the advantage of ML-PBFT algorithm is more obvious, and the average latency decreases from 51.67ms to 34.95ms.Compared with Fig. 4(a), the transaction latency of PBFT algorithm in Fig. 4(b) basically remains unchanged, while that of ML-PBFT algorithm grows significantly, but it is still lower than that of PBFT algorithm.



(a) There is no Byzantine node



(b) There are Byzantine nodes

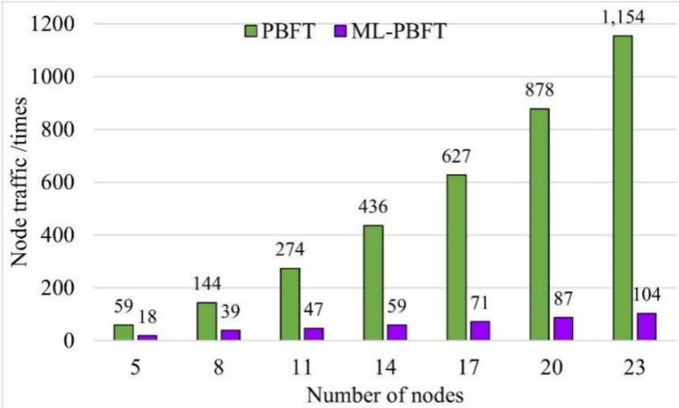
Figure 4. Comparison of transaction delays between the two algorithms

2) Communication overhead

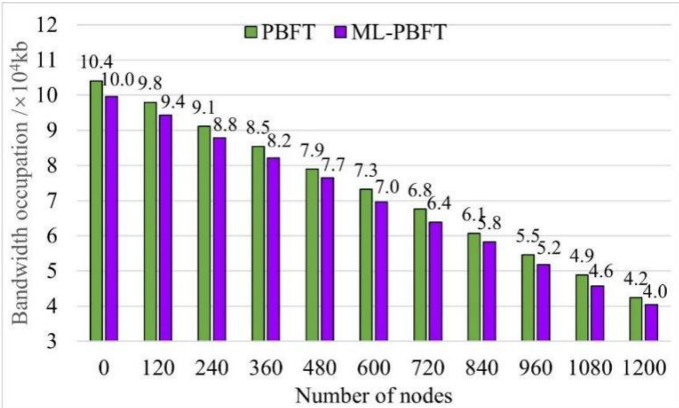
The communication overhead refers to the communication volume generated by the nodes in the network during the consensus process. A comparison of the communication volume of the two algorithms is shown in Fig. 5, where (a) and (b) denote the comparison of the communication volume of a single transaction and the comparison of the bandwidth change during operation, respectively.

In Fig. 5(a), the communication volume of ML-PBFT algorithm grows linearly with the increasing number of nodes in the network. Whereas the PBFT algorithm needs to complete the consensus by communicating through nodes with complexity $O\left(N^2\right)$, its communication volume grows rapidly. Therefore, it can be seen that the ML-PBFT algorithm reduces the communication overhead of the network and is effective.

In Fig. 5(b), the number of nodes in the network is set to be 5. The client sends 1200 request messages and records the bandwidth information every 120ms to observe the change in bandwidth within 1s. Assuming that the size of each message is 12kb. it can be seen that during the execution of the algorithm, the bandwidth occupation of the ML-PBFT algorithm is smaller than that of the PBFT algorithm, which reduces the pressure on bandwidth in the consensus process to a certain extent.



(a) Comparison of single transaction traffic



(b) Comparison of bandwidth changes during operation

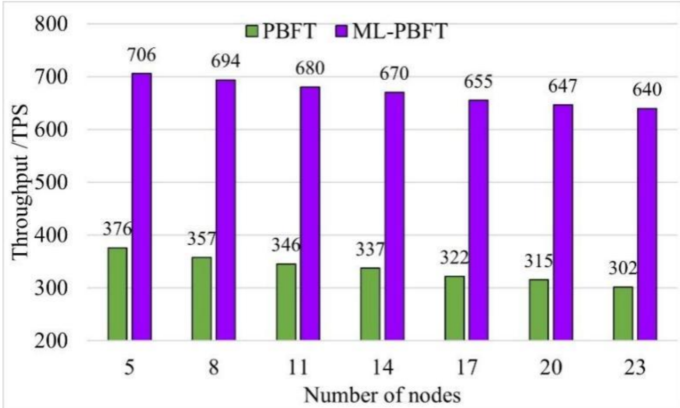
Figure 5. Comparison of communication traffic between the two algorithms

3) Throughput

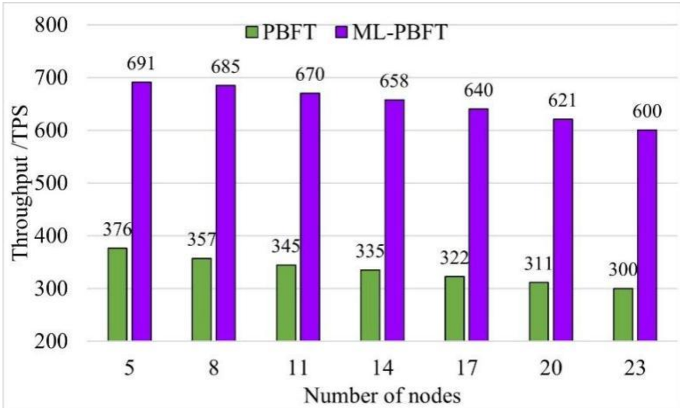
Throughput refers to the number of transactions completed in a unit of time, which is generally represented by TPS. In the experiment, the client is set to send 3000 requests to record the number of transactions that can complete the consensus per second, and the test is conducted with different numbers of nodes. The throughput comparison of the two algorithms is shown in Fig. 6, where (a) and (b) denote the two cases of no Byzantine nodes and presence of Byzantine nodes, respectively.

In Fig. 6(a), the throughput of both algorithms shows a decreasing trend as the number of nodes in the network increases, but in general, the throughput of the ML-PBFT algorithm is much higher than that of the PBFT algorithm, whose average throughputs are 670 TPS and 336 TPS, respectively.

In Fig. 6(b), it can be seen that with the increase in the number of nodes in the network, the throughput of both algorithms also shows a decreasing trend, and the decreasing trend of the ML-PBFT algorithm is larger, but the throughput of the ML-PBFT algorithm is still larger than the throughput of the PBFT algorithm.



(a) There is no Byzantine node



(b) There are Byzantine nodes

Figure 6. Comparison of the throughput of the two algorithms

(2) Dunhuang Cultural Heritage Intelligent Data Resource Management System Testing

1) Test environment

The Dunhuang cultural heritage smart data resource management system in this paper is deployed in local LAN servers with a total of 6 servers, Fabric blockchain network and IPFS privatized cluster are deployed on 6 servers, and the service layer backend is deployed on 1 server. The server hardware configuration of the system is shown in Table 1, and the software environment configuration of the system is shown in Table 2.

Table 1. Server hardware configuration

CPU	**Intel Core i7 14700F**
Memory	32GB
Operating system	Ubuntu 25.10 LTS

Table 2. Software environment configuration

Hyperledger Fabric	**fabric 2.4.4**
IPFS	java-ipfs_v0.35.0_linux-amd64
Go	go 1.25.0 linux/amd64
Docker	docker version 28.2.2
Git	git version 2.48.1
Java	JDK 8

2) System performance testing

In the blockchain network built based on Fabric, the execution performance of smart contract queries and updates is a key indicator for measuring the system's performance. The official Hyperledger Fabric project provides the Caliper testing tool, which can analyze indicators such as transaction throughput, transaction latency, and hardware resource consumption in the Fabric blockchain system, providing support for the subsequent performance tests in this section.

This section selected the four most commonly used smart contracts in the system for testing. The queries and updates of the smart contracts are shown in Table 3.

Table 3. Querying and updating smart contracts

Name of smart contract	Type	Notes
STSC	Update	Publish task requirements
SISC	Update	Upload the result of the task execution
QTSC	Query	Query the task requirement information
QRSC	Query	Check the workers' credit value

In the test experiments in this section, 10 rounds of blockchain network stress tests are designed, in which the first 5 rounds of tests are update type smart contract tests aiming to test the node's ledger writing performance. The latter 5 rounds of tests are query type smart contract tests, aiming to test the node's ledger reading performance. The transaction volume of each round of testing is set to 900, and the speed gradient of transaction writing in each round is set to 60tps, 120tps, 240tps, 360tps, and 480tps.

The test results are shown in Table 4. From the data in the table, it can be seen that the blockchain network can operate stably in each round of testing, and the transaction success rate is 100%. When the transaction sending speed is below 360tps, the performance of smart contracts for updating and querying is stable. When the transaction writing speed is at 360tps, the performance of updating smart contracts decreases slightly, and querying smart contracts are not affected. When the transaction writing speed is 480tps, the performance of both update and query smart contracts is slightly degraded, but the system does not generate obvious lag. Therefore, it can be assumed that the performance of the Fabric blockchain network meets the target expectation.

Table 4. Stress test data of Fabric blockchain network

Test rounds	Successful trading volume.	Failed trading volume	Transaction sending speed (tps)	Throughput (tps)	Average transaction delay (s)
1	900	0	60	60	0.16
2	900	0	120	120	0.14
3	900	0	231	224	0.27
4	900	0	330	236	2.65
5	900	0	354	267	3.91
6	900	0	60	60	0.02
7	900	0	120	120	0.06
8	900	0	240	240	0.24
9	900	0	360	360	0.45
10	900	0	432	418	2.08

3) System Security Analysis

In this section, four crowdsourcing systems are selected to compare with this paper's system: two typical centralized crowdsourcing systems, Mturk and EFF, and two blockchain-based crowdsourcing systems, ZebraLancer and CrowdBC.The comparison of security of crowdsourcing systems is shown in Table 5.

The comparison results show that compared with the traditional centralized crowdsourcing system, the Dunhuang cultural heritage smart data resource management system in this paper has significant advantages in terms of robustness and trustworthiness with the help of the characteristics of blockchain technology. Compared with the same type of decentralized crowdsourcing system, the system in this paper has significant advantages in crowdsourcing matching, task result auditing and crowdsourcing data authorization sharing.

Table 5. Comparison of the security of crowdsourcing systems

Features	System				
	Mturk	**EFF**	**ZebraLancer**	**CrowdBC**	**This article's system**
System robustness	×	×	√	√	√
Do not rely on trusted third parties	×	×	×	√	√
Prevent free-rider attacks	×	√	√	√	√
Prevent attacks on false reports	×	√	√	√	√
Prevent collusion attacks	×	×	×	×	√
Crowdsourcing matching has high accuracy	×	×	×	×	√
Trustworthy review of task results	×	×	×	×	√
Crowdsourced data authorization sharing	×	×	×	×	√

4. Study on the factors influencing the digital dissemination of World Heritage properties

This chapter combines the SOR theory, constructs a structural equation model, and selects the intangible cultural heritage of Anhua black tea production techniques as a specific research object to explore the influencing factors of world heritage value dissemination under the perspective of digital humanities, so as to lay the foundation for designing the world heritage value dissemination mechanism.

4.1. Research Theory and Methodology

(1) S-O-R theory

The S-O-R theory model originated in psychology and is mainly used to explain the influence of external environmental factors on users' psychological and behavioral responses. The model consists of three parts, which are environmental stimulus, organism state and organism response. Where S stands for environmental stimulus, this stimulus can be a stimulus from the external environment, such as politics, culture, economy and other uncontrollable factors, can be a marketing method, such as merchandise promotional discounts, or can be a symbol. The external stimulus will have an effect on the organism, O represents the mediating variable organism state, which refers to the inner activity of the individual who is subjected to the external stimulus, and R represents the organism reaction, which refers to the tendency or avoidance behavior of the individual who is subjected to the external stimulus after the emotional change.

The SOR model is shown in Figure 7. People do not live in a vacuum and are easily influenced by external factors. For example, visual and auditory environmental stimuli (S) act on the individual, will first have an impact on the internal state of the organism (O), and then will control and influence people's behavior (R).

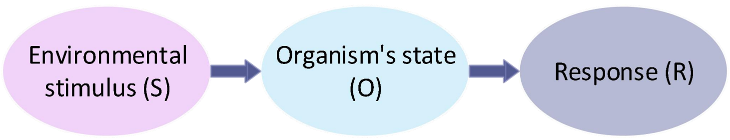


Figure 7. SOR mode

(2) Structural Equation Modeling

Structural equation modeling (SEM) is a statistical method to analyze the relationship between variables based on the covariance matrix of the variables, which is flexible and can better solve the measurement problem of abstract variables.SEM consists of measurement model and structural model, in which the measurement model can reflect the relationship between the indicator and latent variables, and its expression is:

$$X = \Lambda_x \alpha + \delta \tag{1}$$

$$Y = \Lambda_y \beta + \varepsilon \tag{2}$$

In Eqs. (1) to (2): X is the vector consisting of the observed variables of the exogenous latent variables. Y is the vector consisting of observed variables of endogenous latent variables. α is the exogenous latent variable. β is the endogenous latent variable. Λ_x denotes the relationship between X indicators and α latent variables. Λ_y denotes the relationship between Y indicator and β latent variable. δ , ε denote the measurement error vector, which is the unexplained part of the latent variables.

The structural model can reflect the functional relationship between the latent variables with the expression:

$$\beta = \xi\beta + \gamma\alpha + \mu \tag{3}$$

In equation (3): ξ denotes the relationship between endogenous latent variables. γ denotes the effect of exogenous latent variables on endogenous latent variables. μ denotes the residual term of each latent variable.

4.2. Model Design and Research Assumptions

(1) Research model construction

Based on the SOR theoretical model, this paper explores the influence of world heritage projects on audience behavioral intentions. Combined with the research results of the existing literature, it is determined that the research variables of the S part of the media information stimulation factor in this study consist of four variables: media interactivity (MI), media universality (MU), and the originality of the information content (OE), and the closeness to life (CTL), while the research variables of the O part of the user feeling factor consist of four variables: the audience's perceived usefulness (PU), perceived ease of use (PEU), perceived entertainment (PE), and empathy (CE). (PE), empathy (CE), and the behavioral willingness factor R consists of the individual's behavioral willingness to experience, promote, and consume through the digital communication of world heritage.

In this study, a model framework of the influence of digital communication of World Heritage on audience's behavioral willingness was initially constructed, as shown in Figure 8, with media characteristics as the independent variable, individual perception as the mediator variable, and audience's behavioral willingness as the dependent variable.

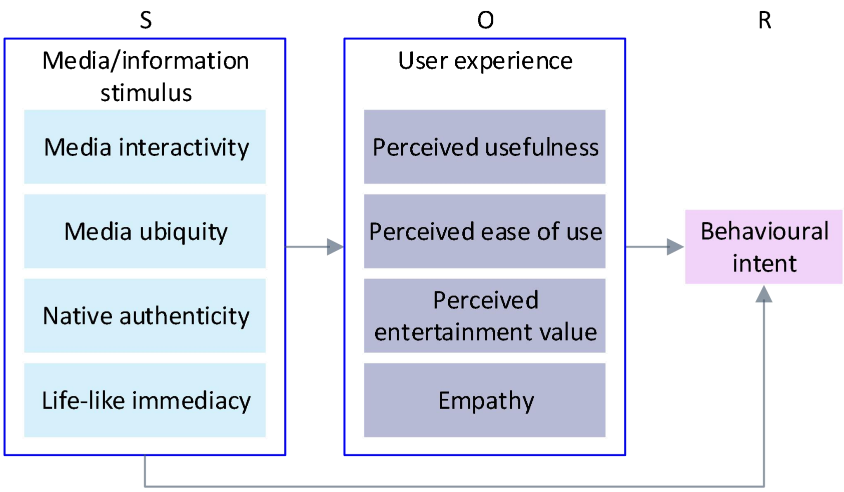


Figure 8. The preliminary construction of the influencing factor model

(2) Research hypotheses

This paper proposes the following hypotheses:

H1: Media interactivity (MI), media universality (MU), and originality (OE) and closeness to life (CTL) of information content in media information characteristics S have a significant positive effect on user perception factor O (H1.1~H1.16).

H2: Media interactivity (MI), media universality (MU), and originality (OE) and closeness to life (CTL) of information content in media information characteristics S have a significant positive effect on audience behavioral intention R (H2.1~H2.4).

H3: User feeling factor O in perceived usefulness (PU), perceived ease of use (PEU), perceived entertainment (PE), and empathy (CE), has a significant positive effect on audience behavioral intention R (H3.1~H3.4).

H4: User perception factor O mediates between media information characteristics S and audience behavioral intention R (H4.1~H4.16).

4.3. Data collection and descriptive analysis

The questionnaire used a 5-point Likert scale to quantify the respondents' attitudes, and was administered to people in Yiyang City, Hunan Province, China, with a focus on screening the cultural tourism industry and black tea practitioners. A total of 92 questionnaires were distributed, and after excluding 6 invalid questionnaires, 86 questionnaires were valid, with a validity rate of 93.48%. The age of the respondents was concentrated in 31~50 years old (79.07%), and the occupation of office workers (81.40%) was the core audience. The degree of understanding of the black tea production technology shows that 56.98% of the respondents "slightly understand", indicating that the publicity and coverage of Yiyang black tea production technology, as a national non-legacy, are still insufficient.

4.4. Reliability analysis

(1) Reliability analysis

The overall scale Clonbach Alpha coefficient was 0.957, indicating a very high internal consistency. The Alpha value after the deletion of each question item is close to the overall value, and the reliability of the scale is very high.

(2) Validity analysis

The KMO value is 0.892>0.70, and the Bartlett's test $P<0.01$ indicates that the variables are significantly related and the questionnaire structure is reliable and valid.

4.5. Correlation analysis

Correlation can be interpreted as when there is a certain relationship between the observed variables, but the causal relationship between them can not be judged, this study uses SPSS28.0 data analysis software, using Pearson correlation analysis, to correlate the correlation analysis of the research data.

The data of Pearson correlation analysis is shown in Table 6, which explains the correlation between the variables more satisfactorily. It can be seen that there is a significant correlation between the influencing factors of media interactivity, media pervasiveness, originality, and closeness to life and perceived usefulness, perceived ease of use, perceived entertainment, empathy, and audience's behavioral willingness, respectively, and there is also a significant correlation between perceived usefulness, perceived ease of use, perceived entertainment, and empathy and audience's behavioral willingness, respectively. As an example, the Pearson correlation coefficients between the influencing factors of media interactivity, media universality, originality, and closeness to life and perceived usefulness, respectively, have the values of 0.502 ($P<0.01$), 0.459 ($P<0.01$), 0.591 ($P<0.01$), and 0.632 ($P<0.01$), and are therefore significantly correlated and can be analyzed in the next step.

Table 6. Correlation analysis among influencing factors

	MI	MU	OE	CTL	PU	PUE	PE	CE	R
MI	1								
MU	0.495**	1							
OE	0.562**	0.615**	1						
CTL	0.414**	0.512**	0.613**	1					
PU	0.502**	0.459**	0.591**	0.632**	1				
PUE	0.513**	0.475**	0.596**	0.595**	0.758**	1			
PE	0.501**	0.524**	0.592**	0.586**	0.694**	0.772**	1		
CE	0.417**	0.458**	0.523**	0.463**	0.602**	0.595**	0.732**	1	
R	0.476**	0.477**	0.541**	0.541**	0.705**	0.734**	0.776**	0.753**	1

4.6. Path analysis

The reliability of the questionnaire was tested above, and in this section, structural equation modeling will be used for path analysis. The following fit indicators are measured to determine whether the judgment structural equation model can be established, and the results of the structural equation model fit are shown in Table 7. It can be seen that the overall fit of the model is good.

Table 7. The fit degree of the structural equation model

Measurement index	CMIN/DF	GFI	AGFI	NFI	TLI	CFI	RMSEA
Measurement results	1.902	0.947	0.926	0.953	0.972	0.983	0.056
Fitting standard	<3	<2	<2	<2	<2	<2	<0.08
Fitting situation	Good	Better	Better	Better	Better	Better	Better

After confirming the effectiveness of the fit, a path analysis was performed, which was done to test the degree of significance and the coefficient of association between the variables. The results of the path analysis of the structural equation model are shown in Table 8.

From the path coefficients of the variables between external stimulus (S) and organism (O) in the structural equation modeling:

Media interactivity (MI), media universality (MU), and the originality (OE) and closeness to life (CTL) of the information content have a significant positive effect on perceived usefulness (PU), perceived ease of use (PEU), perceived entertainment (PE), and empathy (CE) ($p<0.05$).

Media interactivity (MI), media universality (MU), and originality of information content (OE), and closeness to life (CTL) have significant positive effects on audience behavioral intention R ($p<0.05$).

Perceived Usefulness (PU), Perceived Ease of Use (PEU), Perceived Entertainment (PE), and Empathy (CE), all have significant positive effects on audience behavioral willingness R ($p<0.05$).

That is, hypotheses H1, H2, and H3 are valid.

Table 8. Structural equation model path analysis

Hypothesis	Path	Non-standardized path coefficient	S.E.	C.R.	P	Standardized path coefficient	Whether the hypothesis holds true
H1.1	MI→PU	0.358	0.054	3.237	0.002	0.338	Established
H1.2	MI→PEU	0.391	0.082	4.355	0.007	0.363	Established
H1.3	MI→PE	0.309	0.084	4.403	0.007	0.273	Established
H1.4	MI→CE	0.360	0.066	3.629	0.005	0.333	Established
H1.5	MU→PU	0.314	0.100	5.035	0.002	0.282	Established
H1.6	MU→PEU	0.328	0.056	3.430	0.008	0.303	Established
H1.7	MU→PE	0.343	0.070	5.560	0.001	0.325	Established
H1.8	MU→CE	0.367	0.083	5.705	0.010	0.327	Established
H1.9	OE→PU	0.285	0.061	2.233	0.006	0.275	Established
H1.10	OE→PEU	0.205	0.055	6.883	0.003	0.174	Established
H1.11	OE→PE	0.224	0.099	2.390	0.006	0.196	Established
H1.12	OE→CE	0.279	0.108	5.433	0.002	0.238	Established
H1.13	CTL→PU	0.385	0.083	6.875	0.003	0.343	Established
H1.14	CTL→PEU	0.257	0.072	3.225	0.008	0.234	Established
H1.15	CTL→PE	0.367	0.090	2.253	0.006	0.36	Established
H1.16	CTL→CE	0.200	0.074	4.388	0.005	0.159	Established
H2.1	MI→R	0.308	0.053	4.011	0.010	0.282	Established
H2.2	MU→R	0.361	0.094	6.937	0.004	0.324	Established
H2.3	OE→R	0.263	0.070	2.716	0.010	0.226	Established
H2.4	CTL→R	0.266	0.067	3.968	0.001	0.234	Established
H3.1	PU→R	0.393	0.061	6.714	0.010	0.384	Established
H3.2	PEU→R	0.368	0.062	3.185	0.010	0.352	Established
H3.3	PE→R	0.334	0.051	5.344	0.004	0.301	Established
H3.4	CE→R	0.353	0.069	2.817	0.002	0.321	Established

4.7. Mediated effects test

Mediating effects analysis is an important step in testing whether a variable becomes a mediating variable and to what extent it plays a mediating role. When the mediating variable and the antecedent variable exist in the model at the same time, the antecedent variable still significantly affects the dependent variable. Therefore, it can be recognized that the quantity is partially mediated, and the antecedent variable can either directly affect the dependent variable or affect the dependent variable through the mediating variable. According to the SOR model set up in this paper, the mediating effect means that the influence relationship between variables S and R is not a direct causal leading relationship but is generated through the indirect influence of a variable O. At this time, we call the organism O as the mediating variable quantity, and the indirect influence of the stimulus S on the response R through the organism O is called the mediating effect.

According to the model, there are four mediating variables in this paper which are Perceived Usefulness (PU), Perceived Ease of Use (PEU), Perceived Entertainment (PE), and Empathy (CE), and the four mediating variables are analyzed so as to verify whether the hypothesis H4 is valid.

Based on the bootstrap method of structural equation modeling in Amos software, the mediating effect test was conducted by repeating the sample 5,000 times, calculating 95% confidence intervals, and analyzing the effect (Estimate) as well as the P-value of each path. The mediating effects are shown in Table 9.

From the results in the table, the mediating effects of the four mediating variables of Perceived Usefulness (PU), Perceived Ease of Use (PEU), Perceived Entertainment (PE), and Empathy (CE) on the variables of Medium Interactivity (MI), Medium Universality (MU), Originality of the Information Content (OE), and Closeness to Life (CTL) to influence the willingness to R of the audience's behavior are all present ($p<0.05$).

Table 9. Mediating effect

Hypothesis	Path	Estimate	S.E.	Lower	Upper	P	Whether the hypothesis holds true
H4.1	MI→PU→R	0.253	0.050	0.199	0.002	0.001	Established
H4.2	MI→PEU→R	0.274	0.076	0.151	0.007	0.001	Established
H4.3	MI→PE→R	0.215	0.106	0.180	0.007	0.002	Established
H4.4	MI→CE→R	0.252	0.059	0.154	0.005	0.011	Established
H4.5	MU→PU→R	0.221	0.089	0.145	0.002	0.007	Established
H4.6	MU→PEU→R	0.231	0.065	0.201	0.008	0.005	Established
H4.7	MU→PE→R	0.239	0.065	0.180	0.001	0.004	Established
H4.8	MU→CE→R	0.258	0.088	0.189	0.010	0.001	Established
H4.9	OE→PU→R	0.200	0.072	0.155	0.006	0.000	Established
H4.10	OE→PEU→R	0.148	0.064	0.169	0.003	0.002	Established
H4.11	OE→PE→R	0.156	0.084	0.189	0.006	0.004	Established
H4.12	OE→CE→R	0.191	0.102	0.159	0.002	0.001	Established
H4.13	CTL→PU→R	0.271	0.095	0.198	0.003	0.002	Established
H4.14	CTL→PEU→R	0.182	0.085	0.176	0.008	0.006	Established
H4.15	CTL→PE→R	0.256	0.104	0.136	0.006	0.012	Established
H4.16	CTL→CE→R	0.138	0.044	0.129	0.005	0.008	Established

5. Design of World Heritage Communication Mechanisms based on Digital Humanities Perspectives

Based on the results of the previous research, this chapter takes intangible cultural heritage as the object, and carries out an innovative design of the communication mechanism of world heritage under the perspective of digital humanities.

5.1. Selection of communication subjects

(1) Emphasize the content characteristics and innovation of digital communication of intangible cultur heritage.

It is necessary to build a content innovation system for digital communication of intangible cultur heritage, construct a multi-category intangible cultur heritage communication mechanism based on emerging digital technology, and create a characteristic intangible cultur heritage content creation and communication system relying on the in-depth connotation and historical and cultural value of intangible cultur heritage, so as to lead the new wind direction of intangible cultur heritage communication.

(2) Enhance the media literacy of intangible cultur heritage bearers to play the role of digital communication.

To enhance the media literacy and self-communication consciousness of NHIs, pay attention to the role of NHIs in the process of digital communication of NHIs, give full play to their advantages and resources as NHIs, enhance their media cognition and basic operation ability, and promote the digital communication of NHIs from within.

(3) Encouraging the synergy of multi-party bodies to promote the digital dissemination of Ganzi's intangible cultur heritage

With the power of network opinion leaders, universities, private capital, non-profit organizations and other multi-party subjects, the influence and popularity of intangible cultur heritage in the field of digitalization can be expanded, and the digitalization and marketization of intangible cultur heritage industry can be driven to the development process.

5.2. Technical Options for the Digital Dissemination of intangible cultur heritages

(1) Establishing a mass digital media-based intangible cultur heritage communication ecology

Firstly, the important position of media universality in the process of digitalization and dissemination of Ganzi's intangible cultur heritage should be emphasized. Combined with the current situation of intangible cultur heritage resources and the audience's media habits, appropriate mass media and digital technology should be selected to digitize and disseminate the intangible cultur heritage.

Secondly, focus on the role of media interactivity in the digital dissemination of Ganzi's intangible cultur heritage. In the intangible cultur heritage museums, tourist attractions and other areas, some of the intangible cultur heritage digital media equipment with lower maintenance cost and stronger interaction are constructed to promote and disseminate the intangible cultur heritage in Ganzi.

Finally, to build a three-dimensional intangible cultur heritage digital communication system, first of all, we should promote the in-depth integration of media, give full play to the role of the Internet platform, and vigorously carry out the construction of intangible cultur heritage digital experience interactive equipment as early as possible, and build a media communication matrix adapted to the "Internet +".

(2) Explore the trend of intangible cultur heritage communication with the help of cutting-edge digital technology.

Cutting-edge technology can specifically promote the process of digitized communication of intangible cultur heritage in the following two aspects. First, relying on data mining and AI technology, strengthen the function of display and dissemination of ICH, and realize the accurate dissemination of ICH. The second is to integrate digital media resources, expand the digital communication path of ICH, and realize the cross-circle communication of ICH culture.

(3) Formulate the norms of digital communication of intangible cultur heritage based on technical ethics

On the one hand, it is necessary to pay attention to the important position of national intangible cultur heritage communication in mass culture communication. On the other hand, the digitization of ICH should retain the original ecological nature of ICH as much as possible, and formulate new norms for the digital dissemination of ICH under the ethical boundaries positioned by technological intermediaries.

5.3. Selection of paths for the digital dissemination of NRHs

(1) Cultivate compound talents to meet the demand of intangible cultur heritage dissemination

For the long-term development of digital construction and dissemination of intangible cultur heritage, combined with the actual situation of intangible cultur heritage, through cooperation with universities to jointly cultivate intangible cultur heritage digitization of composite talents, but also through the introduction of talents and other policies to attract professionals to jointly promote the digitization of Ganzi intangible cultur heritage process.

(2) Based on the diffusion space to open up the path of non-legacy dissemination

Firstly, build a mechanism for the dissemination and interaction of national intangible cultur heritage, establish a multi-channel and all-round digital media matrix, and promote the comprehensive development of the ethnic areas relying on the digital dissemination of intangible cultur heritage.

Secondly, promote the development of cultural and creative products of intangible cultur heritage and their derivatives, make full use of the Internet communication media, promote the sustainable development of the digital protection and dissemination of intangible cultur heritage, and deeply excavate and develop the cultural value and market space of intangible cultur heritage and their derivatives.

(3) Adhere to the principle of digital protection of intangible cultur heritage to promote the benign development of intangible cultur heritage.

In the process of promoting the digital dissemination of non-legacy, it is necessary to adhere to the basic principles of non-legacy protection, carry out relevant work in an orderly manner under the guidance of national and local policies, and at the same time, sort out and formulate a working mechanism applicable to the digital protection and dissemination of local national non-legacy in the light of its own actual situation.

(4) Shaping digital brands to realize the international dissemination of ICHs

The digitization of intangible cultur heritage can also transform traditional cultural resources into economic resources, explore its economic value, and promote the development of intangible cultur heritage industry with the mechanism of productive and market-oriented protection. Push the intangible cultur heritage products to the market front, take the road of intangible cultur heritage industrialization, and shape the intangible cultur heritage cultural brand for brand dissemination. By shaping the digital IP and brand image of non-legacy and then forming the social influence of non-legacy culture, thus expanding the communication power of non-legacy.

(5) Deeply integrating into the cultural tourism industry to enhance the digital communication power of intangible cultur heritage

By combining with tourism, the accurate digital dissemination of non-fraditional heritage can be realized. Tourists' willingness to travel and action to a large extent comes from the curiosity of different cultures, it is because of the cultural differences between different regions will drive the public to experience and feel, in the rapid development of culture and tourism industry today, tourists should also become an important target of the dissemination of intangible cultur heritage material culture.

(6) Constructing intangible cultur heritage digitalization standards to regulate the intangible cultur heritage dissemination mechanism

Promote the establishment of digital standards for intangible cultur heritage, can vigorously promote the influence and dissemination of intangible cultur heritage in the field of digitalization. Specifically, it can start from two aspects:

One is to use a certain digital technology as a yardstick to establish standards for different categories of intangible cultur heritage items.

The second is to take a certain intangible cultur heritage project as the basis and propose construction standards for the application of different digital technologies.

6. Conclusion

This study constructs a blockchain-based world heritage value co-creation model, realizes the algorithmic interpretation of world heritage value, and explores the influencing factors of the digital communication of world heritage based on the SOR theory and structural equation model, so as to realize the design optimization of the communication mechanism.

Compared with the PBFT algorithm, the WL-PBFT consensus algorithm proposed in this paper reduces the time complexity of the consensus process from $O\left(N^2\right)$ to $O\left(N\right)$, which effectively reduces the communication overhead in the network, and reduces the average latency from 51.67ms to 34.95ms, and average throughput from 336 TPS to 670 TPS.In terms of crowdsourcing matching, crowdsourcing task auditing and crowdsourcing data authorization sharing, the system in this paper shows obvious advantages over both the traditional centralized crowdsourcing system and the same type of crowdsourcing system based on blockchain.

In addition, through the hypothesis testing of the influencing factor model, this paper draws the following conclusions:

(1) The interactivity and universality of the digital communication media of intangible cultur heritage, as well as the original and close-to-life nature of the information content and other media characteristics significantly and positively affect the audience's willingness to experience, promote and consume intangible cultur heritage.

(2) The characteristics of the digital communication media of intangible cultur heritage will also significantly and positively affect the audience's user feelings such as perceived usefulness, perceived ease of use, perceived entertainment and empathy, which will also positively affect the user's behavioral willingness.

(3) Non-legacy digital communication media features can positively influence users' behavioral willingness by influencing users' feelings, and users' feelings play an intermediary role in this process.

This paper puts forward targeted suggestions from the three aspects of subject selection, technology selection and path selection of digital communication of intangible cultur heritage: taking content innovation as the core, the participation of intangible cultur heritage bearers as the highlight, the synergy of multiple subjects as the support, the mass digital media as the support, the cutting-edge digital technology as the pilot, the technical ethics as the boundary, the diffusion space as the guidance, the principle of digital protection of intangible cultur heritage as the basis, the digital branding as the pedal, and the cultivation of complex talents as the basis. The specific measures and countermeasures are based on the principle of digital protection of NRH, digital branding, cultivation of complex talents, and combination of culture and tourism industry, with a view to improving the social influence of digital communication of NRH.

About the Author

WuShangqian, Female, Tujia ethnicity, born in Xianfeng County, Hubei Province, CHINA, attending Doctoral studies at Centre for Global Archaeologicai Research USM, the main research direction is the interpretation of world heritage and heritage management.
Suresh Narayanen, male, Senior Lecturer of Centre for Global Archaeological Research, Universiti Sains Malaysia.

References

1. Santa-Cruz, F. G., & López-Guzmán, T. (2017). Culture, tourism and world heritage sites. Tourism management perspectives, 24, 111-116.
2. Adie, B. A., & Hall, C. M. (2017). Who visits World Heritage? A comparative analysis of three cultural sites. Journal of Heritage Tourism, 12(1), 67-80.
3. Kim, H., Oh, C. O., Lee, S., & Lee, S. (2018). Assessing the economic values of World Heritage Sites and the effects of perceived authenticity on their values. International Journal of Tourism Research, 20(1), 126-136.
4. Osipova, E., Emslie-Smith, M., Osti, M., Murai, M., Åberg, U., & Shadie, P. (2020). IUCN World Heritage Outlook 3: A conservation assessment of all natural World Heritage sites, November 2020. Gland, Switzerland: IUCN. x+ 90pp.
5. Andersen, J. (2020). Understanding and interpreting algorithms: toward a hermeneutics of algorithms. Media, Culture & Society, 42(7-8), 1479-1494.
6. Zou, C., & Zhang, F. (2022). Algorithm interpretation right-the first step to algorithmic governance. Beijing L. Rev., 13, 227.
7. Seaver, N. (2017). Algorithms as culture: Some tactics for the ethnography of algorithmic systems. Big data & society, 4(2), 2053951717738104.
8. Jannidis, F., Kohle, H., & Rehbein, M. (2017). Digital Humanities. JB Metzler.
9. Terras, M. (2015). Crowdsourcing in the digital humanities. A new companion to digital humanities, 420-438.
10. Luhmann, J., & Burghardt, M. (2022). Digital humanities—A discipline in its own right? An analysis of the role and position of digital humanities in the academic landscape. Journal of the Association for Information Science and Technology, 73(2), 148-171.
11. Faull, K. M. (2022). Digital Humanities and Cultural Heritage. Crossroads of Heritage and Religion: Legacy and Sustainability of World Heritage Site Moravian Christiansfeld, 211.
12. Munster, S., Apollonio, F. I., Bell, P., Kuroczynski, P., Di Lenardo, I., Rinaudo, F., & Tamborrino, R. (2019). Digital cultural heritage meets digital humanities. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42(2/W15), 813-820.
13. Sula, C. A. (2015). Digital humanities and digital cultural heritage (alt-history and future directions). Cultural Heritage Information: Access and Management. London: Facet, 13, 36.
14. Zeng, Y. (2025). DIGITALIZATION OF MUSEUMS: A NEW PARADIGM FOR THE PROTECTION AND DISSEMINATION OF CULTURAL HERITAGE. Global Media and Social Sciences Research Journal, 6(1), 317-323.
15. Correia, M., Carlos, G. D., Dipasquale, L., Mecca, S., Vicente, J., & Correia, T. (2020). communication and dissemination of vernacular heritage. Ricerche. Architettura, Pianificazione, Paesaggio, Design, 75.
16. Liu, Z. (2025). The construction of a digital dissemination platform for the intangible cultural heritage using convolutional neural network models. Heliyon, 11(1).
17. Bercigli, M. (2019). Dissemination strategies for cultural heritage: the case of the tomb of Zechariah in Jerusalem, Israel. Heritage, 2(1), 306-314.