Research on the Knowledge Organization of Intangible Cultural Heritage Spatiotemporal Data from a Digital Humanities Perspective

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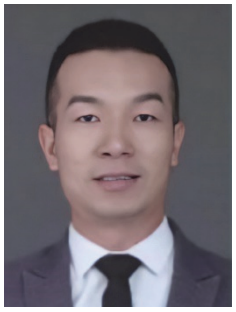

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Abstract: Intangible cultural heritage is an important part of China's excellent traditional culture, and its inheritance and development are attached to a specific time and space. From the digital humanities perspective, the visualization of intangible cultural heritage spatiotemporal data knowledge is important for promoting the protection and inheritance of intangible cultural heritage. Research on the spatiotemporal semantic model of intangible cultural heritage can show the multiple relationships of intangible cultural heritage spaces, which is conducive to the semantic description specification and effective expression of intangible cultural heritage spatiotemporal data.

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1.0 Introduction

Intangible cultural heritage refers to various traditional cultural expressions that have been passed down from generation to generation by people of all ethnic groups around the world and are considered part of their cultural heritage, as well as physical objects and places related to traditional cultural expressions. Intangible cultural heritage is an important component of China's excellent traditional culture, a vivid witness to the continuous transmission of Chinese civilization, and an important foundation for connecting national emotions and maintaining national unity.

Recent research on digital humanities and humanistic computing has drawn scholars' attention to computer science, library information, and history. Scholars are attempting to combine intelligent information processing technology with research on cultural heritage resources to conduct semantic organization research on intangible cultural heritage. With the help of the Semantic Web and machine learning technology, scholars have conducted research on knowledge extraction, knowledge organization, and knowledge services related to library, museum, and archive collection

resources, gradually accumulating relevant theories, methods, and technologies for cultural heritage information resource management.

This article combines knowledge organization theory and ontology to analyze the characteristics of intangible cultural heritage spatiotemporal data in an in-depth manner. It combines semantic description and data association technology to address the fragmentation of intangible cultural heritage spatiotemporal data knowledge, explore the organizational methods of fine-grained digital humanities in resources, and establish a framework for describing intangible cultural heritage digital resources guided by knowledge organization theory, including the collection of intangible cultural heritage data with spatiotemporal characteristics, ontology construction, and associated intelligent data applications. Using intangible cultural heritage in Hubei, China as an example, we construct a digital resource knowledge organization model for intangible cultural heritage knowledge sharing and provide new ways of achieving digital protection and inheritance of intangible cultural heritage.

2.0 Related Research

2.1 Knowledge organization research

Several studies on knowledge organization have been conducted. In 1929, American librarian Bliss (1931) proposed the concept of "knowledge organization." He discussed in detail the principles of book compilation and scientific classification methods in his article. In knowledge services relating to books, scientific organization methods should be adopted to classify all kinds of knowledge. Although Bliss (1931) was the one who proposed the concept of knowledge organization, there are still many ideological disadvantages and contradictions in his classification of knowledge organization. Dahlberg (2010), the founder of the International Knowledge Organization Society, proposed that knowledge organization is a systematic project that aims to reorganize knowledge concepts, arrange them according to the internal structural characteristics and conceptual elements of knowledge, and present the value of knowledge to readers. Recent research on intangible cultural heritage knowledge organization has mainly focused on the internal characteristics of digital cultural resources, including ontology, domain theme construction, and linked data. For example, Lombardo et al. (2016) proposed an ontology model of film and television dramas that could show the relationships between different characters in the drama and provide intelligent applications for the digital display of ancient dramas. Gao et al. (2022) applied ontology technology and GIS technology to visualize changes in Li Bai's spatiotemporal emotional trajectory.

In terms of domain themes, taking Peking Opera and Kunqu Opera as examples, supplemented by the Ontopia theme map development tool, Wang and Xin (2015) established a theme map model of intangible cultural heritage information resources and demonstrated the generation and organization effects of the theme map of such resources. Tan and Zhang (2018) analyzed the characteristics of the cultural space of intangible cultural heritage and proposed a spatiotemporal data model of it. The prototype system established based on this model can dynamically trace back and retrieve inheritors' spatiotemporal information. Regarding linked data, Xia et al. (2016) studied the social relationships between intangible cultural heritage image resources from the perspective of label association, and visually displayed the themes of intangible cultural heritage digital resources by comparing and analyzing the co-label network and associated label network features. Yonghui et al. (2020, 2021) explored the associated data scheme of local poetry resources and constructed a knowledge graph based on a graph database.

Extensive project research on linked data has been conducted. For example, Dbpedia extracts structured data from many entries in Wikipedia, realizes cross-database links on data nodes, and realizes various intelligent knowledge services (Becker and Bizer, 2008). In 2015, the British Library, the National Library of New Zealand, the University of Oxford Library, Harvard University, and others jointly established the International Image Interoperability Framework (IIIF) organization, which uses linked data to uniformly display and use online resources, such as books, maps, scrolls, manuscripts, music scores, and archival materials based on images (IIIF, 2017). With the help of IIIF, libraries and museums can share and present digital content across different platforms through a set of commonly used APIs. Yan and Wang (2018) used symbolic analysis to visualize the relationships between Song Dynasty characters in the CBDB dataset. Ziming et al. (2018) applied relational data technology to the display of visual resources in Dunhuang. In terms of resource description in knowledge organization, a team at Nanjing Agricultural University conducted a series of research on the digitization, semantic knowledge organization, and knowledge base construction of local chronicles based on the university's special collection "Local Records Products" (Xu and Bao, 2019). Wu and Bao (2008) and Wang and Shi (2023) explored the construction of an immovable cultural relic information reference model and an intangible cultural heritage knowledge ontology in the field of architecture based on the CIDOC CRM model. Dong (2005), Jia and Shi (2015), and Zhang (2015) studied relevant models from the perspective of museum metadata standards. In terms of research on knowledge organization–related data, Fan and Lin (2022), Zuo and Ou (2019), and Huang (2012) introduced and examined an integrated

model of cultural heritage data resource association, semantic description of cultural information resources, and reference models in the field of cultural heritage information (i.e., CIDOC CRM, CDWA, and EDM).

Much of the research on knowledge organization at home and abroad has been concentrated in the fields of library information and digital culture. Although there has also been much research on intangible cultural heritage, knowledge organization involving intangible cultural heritage spatiotemporal data is rare. In 2008, Li (2008) proposed, from the perspective of geography, the establishment of a digital resource library through the measurement of cultural heritage using computer graphics and virtual reality technology to provide a new platform for cultural heritage protection and virtual tourism in Hubei, China. Taking cultural relics as an example, Liu and Xu (2020) described linear cultural heritage resources using linked data technology and RDF description to reveal the relationships between resources, which is important for linear cultural heritage knowledge organization.

To sum up, few studies have been conducted on intangible cultural heritage knowledge and most of them have focused on digital humanities, including books and information. This article proposes a knowledge organization framework based on intangible cultural heritage and semantically describes the cultural spatial location and cultural evolution process of intangible cultural heritage. Semantic description, showing the development process of intangible culture in an associative way, helps provide intelligent knowledge services to users. In addition, establishing an intangible cultural heritage knowledge organization model can explore knowledge organization with temporal and spatial characteristics, provide new research ideas for intangible cultural heritage digital visualization, and is important for the inheritance of intangible cultural heritage.

3.0 Analysis of the Spatiotemporal Characteristics of Intangible Cultural Heritage

Intangible cultural heritage resources are dynamic and holistic. When analyzing them, it is necessary to consider the characteristics of time and space and to put forward the core elements related to the content of intangible cultural heritage. Combining intangible cultural heritage and analyzing its content revealed that its development is inseparable from characters, events, time, and phenomena. The following sections describe these five elements.

3.1 Agent's description

The character element is the social practice and cognitive subject of intangible cultural heritage. The development of intangible cultural heritage usually targets human activities, particularly their trajectories and deductions. Characters who have an impact on intangible cultural heritage include not only inheritors but also groups in social activities. These groups inherit Chinese history and culture in the process of social production, labor, and folk activities. Research on the development of intangible cultural heritage takes the inheritor as the main line and records it along with the participants in social activities. Figure 1 shows an analysis of the character elements. An analysis of a single person generally displays the inheritance and skills of intangible cultural heritage, emphasizing the record of skills. Group figures comprise the recording process of intangible cultural heritage activities and the development and interpretation of events, and the emphasis is on social activities.

3.2 Event characteristic analysis

Event elements refer to influential things or behaviors in intangible cultural heritage activities with one or more partic-

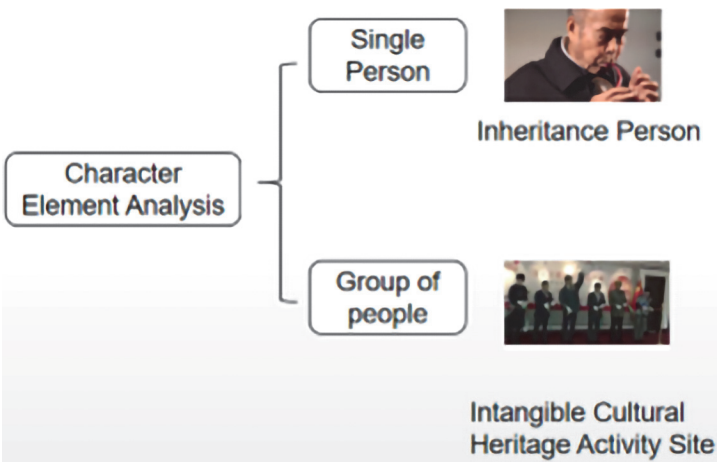

Figure 1. Analysis of character elements

ipants. Events and character elements are closely related and have a two-way relationship. Event elements are the core elements of intangible cultural heritage, and the subject of an event is the person who is the reference of the event and an important factor in the event's occurrence. However, events also have time and space elements, which are inseparable. They are consistent in terms of time—that is, they may develop continuously in time or in a single moment. Similarly, the development of events is inseparable from the span of space. For example, the dragon boat race during the Dragon Boat Festival may be held on the Yangtze River or the Han River. Still, the legend of Qu Yuan related to the Dragon Boat Festival involves spatial changes, including Hubei, Shandong, Henan, Hunan, and other spatial locations. Therefore, regarding the intangible cultural heritage of the Dragon Boat Festival, when the spatial scale is reduced, it may be found that the event includes many subevents. For example, the development of the event after the scale is enlarged is an insignificant part of the historical development process of the Dragon Boat Festival.

3.3 Attribute characteristic analysis

Attribute elements, also known as thematic features, are another important feature of intangible cultural heritage. All physical objects in intangible cultural heritage resources have attributes, generally divided into quantitative and qualitative attributes. Quantitative attributes typically consist of the item number of intangible cultural heritage, the cultural heritage level and data, and others, while qualitative attributes consist of the names, characteristics, and types of intangible cultural heritage. Attributes express rich features, which also play an important role in spatiotemporal data. Therefore, in the study of intangible cultural heritage spatiotemporal data, the connotation of hyper-geographical space must also be considered so that it can become a tool for describing intangible cultural heritage regional characteristics.

3.4 Time characteristic analysis

While relative time, time expresses the time intervals of intangible cultural heritage events. In addition, it can be divided into real-world time and transaction time from a semantic point of view. Real-world time is the real time when an event occurred, and transaction time represents the time when the computer processed the event data. However, from the perspective of knowledge organization, there is not much difference between these two kinds of attributes. In the time expression of intangible cultural heritage, time points, time intervals, and time collection can also be used to express the evolution of events. Specifically, a point in time is a certain moment. In events as intangible cultural heritage, the point in time can be a text description or a specific value. It can be expressed in words such as "Monday" and "20 years of Zhenguan"; it can be expressed using numerical value as 2022.10.22, and it can also be accurate to the hour or even minute and second. The time interval, which represents a time period, is a two-digit line segment that includes the start and end times and the subtraction of the two moments. The time set refers to the union of multiple times, which represents the set of an event's multiple time periods. Time sets can be used to express the periodicity of events, bringing together different time periods and expressing the process of events more clearly. See Table 1 for specific representation methods.

3.5 Spatial feature analysis

Spatial elements are the core elements of intangible cultural heritage resources. They include the spatial location and distribution geometry of such resources. The spatial position expresses the development and location of an activity or event. For example, the dragon boat race during the Dragon Boat Festival is held in Yichang City, Hubei Province. Spatial location can be expressed not only by place names but also by landmarks, coordinates, and addresses. Intangible cultural heritage events or activities are bound to be accompanied by changes in geographical space, which is the full embodiment of cultural space. The superposition of intangible cultural heritage elements, such as events, space, and time, can present the development of and deductive changes in intangible cultural heritage resources. The spatial element is a comprehensive display of the development cycle of cultural heritage and pertains to the changes in people,

Time expression	Meaning	Applications
Point in time	A certain moment	The Dragon Boat Festival is held on June 5.
Time interval	Time slot	Dragon Boat Race dates: June 3–4
Time collection	A collection of multiple time periods for a certain event	Dragon Boat Festival schedule: Sign in at 8:00—8:30 on June 3, 2022. June 3, 2022; 9:00–16:00 – Preliminary round June 4, 2022; 9:00–12:00 – Finals

Table 1. Representation method of the time element

events, and things occurring in a specific cultural activity in a certain space. It is a complex of historical and cultural activities and lifestyles jointly created by a large group of people in a certain time and space, and the cultural form and consciousness precipitated based on this.

4.0 Semantic Model Construction of Intangible Cultural Heritage Spatiotemporal Data

The research framework includes five parts: data acquisition and processing, ontology model, semantic description, knowledge association, and knowledge services for the knowledge organization of intangible cultural heritage spatiotemporal data. The knowledge framework of intangible cultural heritage spatiotemporal data is shown in Figure 2.

It starts with data collection and then analyzes the spatiotemporal distribution characteristics, content, and types of intangible cultural heritage. Thereafter, through ontology construction and knowledge association of intangible cultural heritage spatiotemporal data, it addresses the following shortcomings of the organization of such data: the degree of knowledge coupling is not high, and the data correlation is not strong. In terms of intelligent applications, based on the RDF resource description framework, the research framework describes the objects of intangible cultural heritage spatiotemporal data resources, prompts the semantic relationships between intangible cultural heritage spatiotemporal data, forms data associations, and provides users with knowledge retrieval and digital display services.

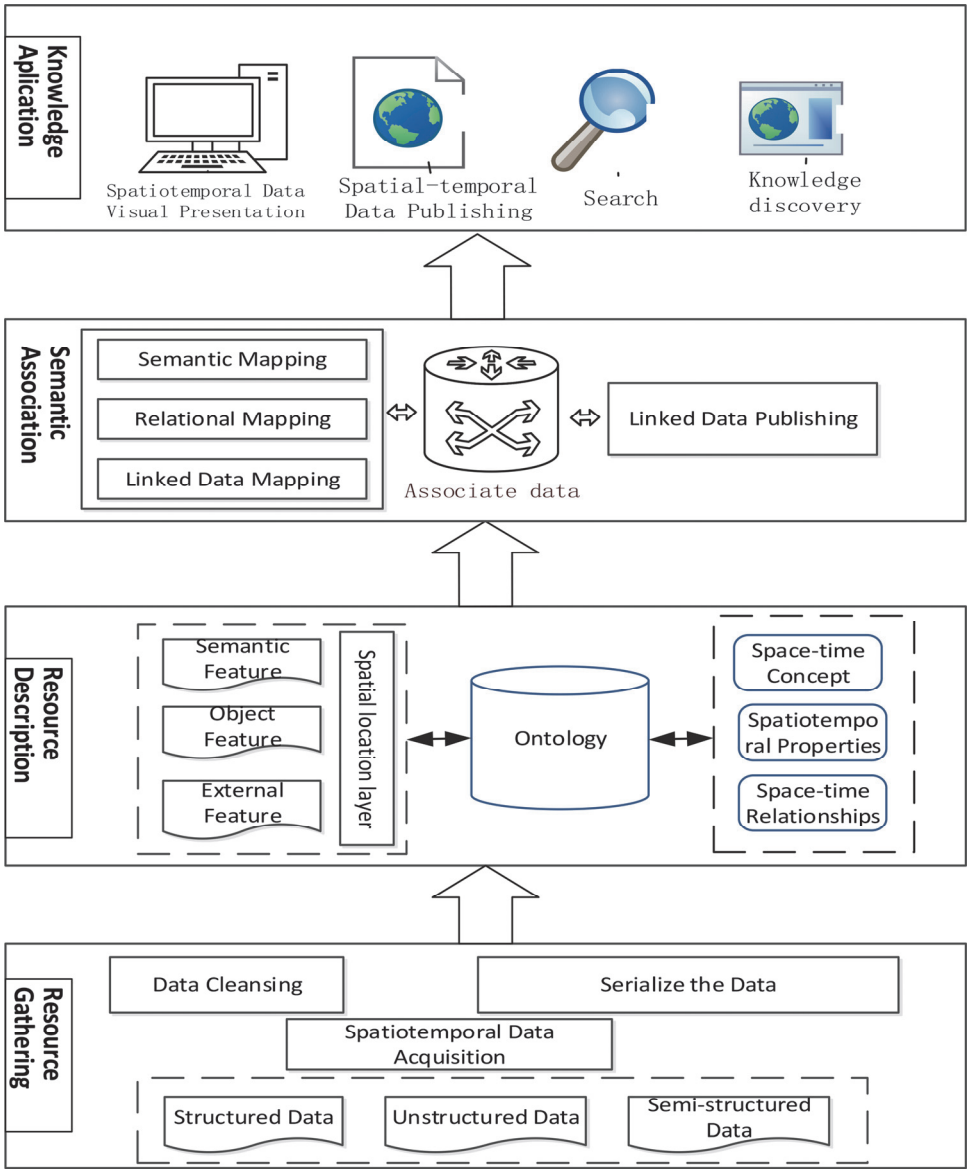

Figure 2. Semantic model framework of intangible cultural heritage spatiotemporal data.

4.1 Data collection and processing

There are many intangible cultural heritage items in China, and network resources and existing digital resources are currently the main sources of knowledge about them. Data resources on intangible cultural heritage include structured, semi-structured, and unstructured data, which are heterogeneous, incomplete, and need to be cleaned centrally. Noise is removed to improve the credibility and accuracy of the data. In knowledge organization, data resources on intangible cultural heritage have different degrees of knowledge granularity and different sources. For users, different needs require different levels of knowledge. Analyzing resource characteristics and granular classification can meet users' differentiated needs.

4.2 Resource description

4.2.1 Resource description hierarchy

Intangible cultural heritage resources include a large amount of resource description information, including resource types and intangible cultural heritage domain knowledge, which can be serialized only through the description. At the semantic description level, different levels have different degrees of granularity, and the semantic structure of intangible cultural heritage may be displayed through a multi-layer structure. This article proposes a semantic description model of intangible cultural heritage spatiotemporal data according to the requirements of user intelligent knowledge services (see Figure 3). At the semantic description level, it is divided into external characteristics, content characteristics, and semantic characteristics from low to high, and the higher these characteristics are, the higher the degree of abstraction. The description of the lower layer is the basis of the upper layer, and the semantic information of the upper layer can be obtained from the semantic feature description of the bottom layer.

External characteristics are generally used to describe resources' external and underlying characteristics. This article refers to Dublin Core (Hereinafter referred to as DC) metadata standards to define the external characteristics of intangible cultural heritage digital resources, including the type, uploader, tag, upload time, creator, cultural size, source of resources, and other information of such resources.

The spatial information layer is an important part of the entire model. It can be described in terms of its three parts: the regional locations of intangible cultural heritage items, the topological relationships between intangible cultural heritage objects, and the spatial semantic relationships. The computer algorithm may automatically extract the location relationship of the region, and the computer method of the region is different. The topological relationship can be

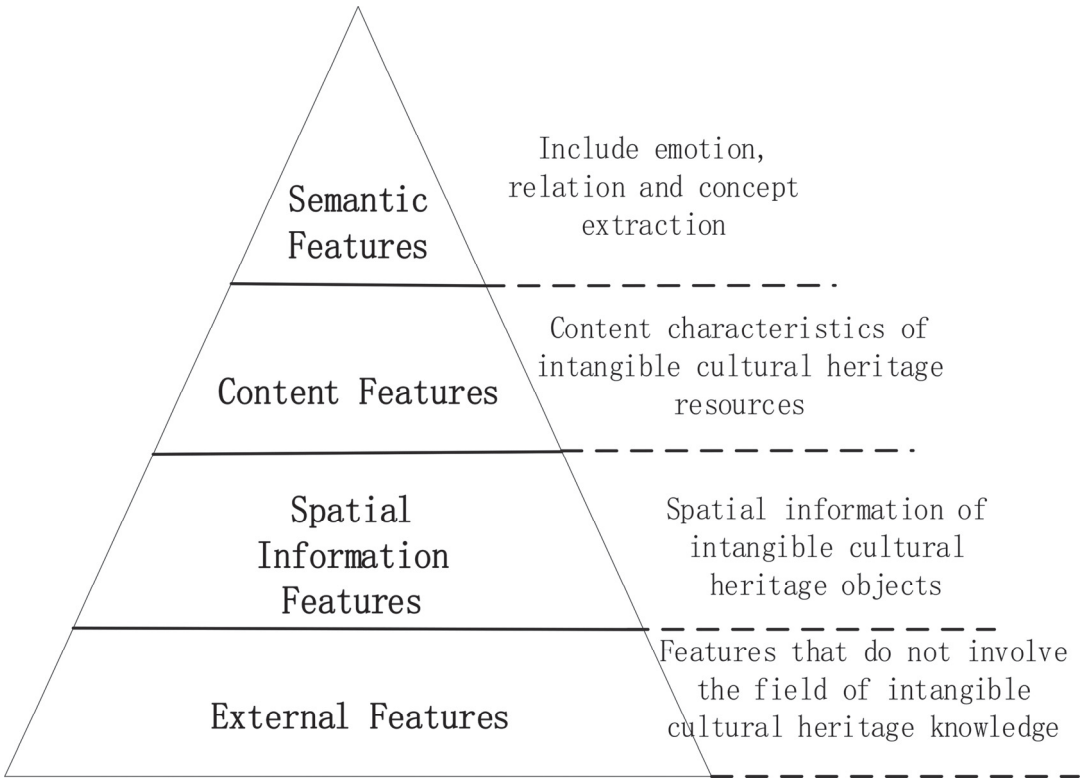

Figure 3. Hierarchy of resource descriptions.

judged according to the spatial location relationship. Spatial semantic relationships refer to the logical relationships between intangible cultural heritage objects and attributes, such as dependencies and subordinations.

The content description is used to describe the specific content of an intangible cultural heritage resource and, at the same time, to highly summarize the content objects of intangible cultural heritage resources, including its inheritors, spatial geographical location, background, and spatial-topological relationship.

Description of the semantic feature layer is the highest level of semantic description. It describes not only the emotions of characters but also the relationships between people, people and things, and things and things, such as the relationships between the inheritors of intangible cultural heritage items and the affiliation relationships between items and organizations. In addition, it reveals the relationship between concepts and emotions and has the function of doctrine reasoning, which can realize the reasoning relationship between knowledge and concepts in the resource domain.

4.2.2 Ontology construction

With the advent of big data, ontology has been widely used as a tool for knowledge services in knowledge organization. The purpose of ontology construction is to analyze the concepts, attributes, and relationships of events to determine whether there are connections between them and to realize the sharing and reuse of intangible cultural heritage knowledge in different resource libraries. Therefore, constructing an ontology model is at the core of the Semantic Web, providing data structure support for the release, digital presentation, and sharing of regional intangible cultural heritage resources.

(1) Determination of the knowledge concept set
The ontology of intangible cultural heritage is a conceptual model for regulating and extracting digital resource bases and is a high-level basis for intangible cultural heritage items. Based on the existing conceptual model, combined with the spatiotemporal characteristics of intangible cultural heritage, the concept of intangible cultural heritage is determined to be constructed by knowledge categories such as intangible cultural heritage items, inheritors, inheritance objects, time, geographical location, events, and intangible cultural heritage item types. This article adopts the 5W1H theory to divide the intangible cultural heritage concept into five dimensions (see Table 2 for the key concept set): (1) Who, about intangible cultural heritage participants, such as inheritors and intangible cultural heritage institutions; (2) What, about the content of intangible cultural heritage, such as the type of intangible cultural heritage item or event; (3) Where, about the geographical location and spatial environment of the intangible cultural heritage; (4) When, about the time when the intangible cultural heritage occurred and the time point where the intangible cultural heritage video is located; and (5) Why, about the reason for the intangible cultural heritage and the situation it is a part of.

(2) Attributes and relationships
In ontology construction, in addition to determining the knowledge concept set, it is also necessary to define the relationships between two or more concepts through attributes. The definitions of intrinsic attributes and relationships are key to ontology construction. The quality of each definition directly affects the concept defined and the expression of semantic relationships. The attribute definition of ontology mainly includes data attributes and object attributes. The object attribute refers to the relationship between intangible cultural heritage items, and the data attribute definition refers to each item attribute's data type. The relationship attributes in

Dimension	Entity description
Who	Inheritors/related personnel
	Institution
What	Projects of intangible cultural heritage
	Event
Where	Geographical location
	Space environment
When	Origin of intangible cultural heritage
	Time of event
How	Event situation

Table 2. Key concept set

intangible cultural heritage include intangible cultural heritage items' relationships with organizations, regions, activities/events, resource types, and origins. The attribute values of the relationships are shown in Table 3.

Data attributes are the data values that describe the concept of intangible cultural heritage itself. Referring to the DC metadata standard and based on the intangible cultural heritage characteristics, the core metadata of intangible cultural heritage includes inheritors, projects, institutions, events, project types, geographical locations, and others. They are abstract and composite objects, and these concepts themselves have attributes such as names, introductions, labels, and levels of intangible cultural heritage projects. Some core metadata attributes are shown in Table 4.

Projects refer to the information on the national intangible cultural heritage list formulated by China, such as item names, serial numbers, item introductions, labels, and grades. Inheritors are the main body and core elements of intangible cultural heritage items, and together with these items, they are important parts of knowledge organization. The regional space is based on the geographical location of the intangible cultural heritage and the administrative area where it is located and expresses the specific distribution of the intangible cultural heritage items in geographical space. In the geographic information space, mining the distribution of intangible cultural heritage items in different dimensions will allow an analysis of the historical changes of intangible cultural heritage and the spatial structures of re-

Relationship	Object properties	Domain	Range
Project and organizations	IC:hasOrganization	owl:Thing	owl:Thing
	IC:isBelongedOf	foaf:Person	foaf:Organization
Project and regions	IC:hasItem	dft:Location	geo:Space
	IC:isLocated	dft:Projec	geo:SpaceThing
Project and activities/events	IC:hasEvents	dft:Project	owl:Thing
Project and resource types	IC:hasType	owl:Thing	owl:Thing
Project and origin	IC:hasTime	dft:Project	dftTimeSpan

Table 3. Relationship attributes

Object Class	Meaning	Data Properties	Range
Intangible cultural heritage project	Name, number, introduction, label, level of intangible cultural heritage project	dft:title	rdf:literal
		dft:profile	
		dft:tag	
		dft:code	rdf:int
		dft:rank	rdf:int
Inheritor	Name, age, gender, skills, ethnicity, and introduction of the inheritor	dft:name	rdf:literal
		dft:age	rdf:int
		dft:skill	rdf:literal
		dft:sex	rdf:literal
		dft:Nationality	
		dft:resume	
Regional space	Landform of intangible cultural heritage distribution area	dft:region	rdf:literal
Event/Activity	The activity and form of the event	dft:acvivity	rdf:literal
		dft:form	
		dft:level	
Organization	Institution Name	dft:Organization	rdf:literal
		dft:telephone	rdf:int

Table 4: Core Data Attribute Table

sources, which play important roles in the historical evolution of intangible cultural heritage and the inheritance of intangible cultural heritage knowledge. Events/activities are intangible cultural heritage inheritance and the display process of intangible cultural heritage items in a specific environment. They are vivid expressions of intangible cultural heritage content. The organizational structure is the corresponding responsible institution or protection organization for the intangible cultural heritage item, which generally includes the unit's name and contact information. These units comprise the main body of intangible cultural heritage protection and undertake the functions of excavation and protection of intangible cultural heritage.

(3) Ontology model

Through the concept set, attribute, and relationship definitions, the UML method is used to build an ontology frame structure, as shown in Figure 4. The subjects in the figure are concepts such as intangible cultural heritage items, inheritors, events/activities, regional spaces, and organizational structures. Each concept has its own independent subset attributes, and the relationships between concepts are formed through object attributes, which constitute the overall conceptual framework of knowledge organization. In the ontology model, each concept has attributes, the relationships between concepts are connected through attributes, and the concepts are connected through extended attributes. The relationships between these attributes and concepts constitute a semantic network. The establishment of an ontology model is conducive to the standardization of the concept of regional intangible cultural heritage and the formation of internal relationships between concepts.

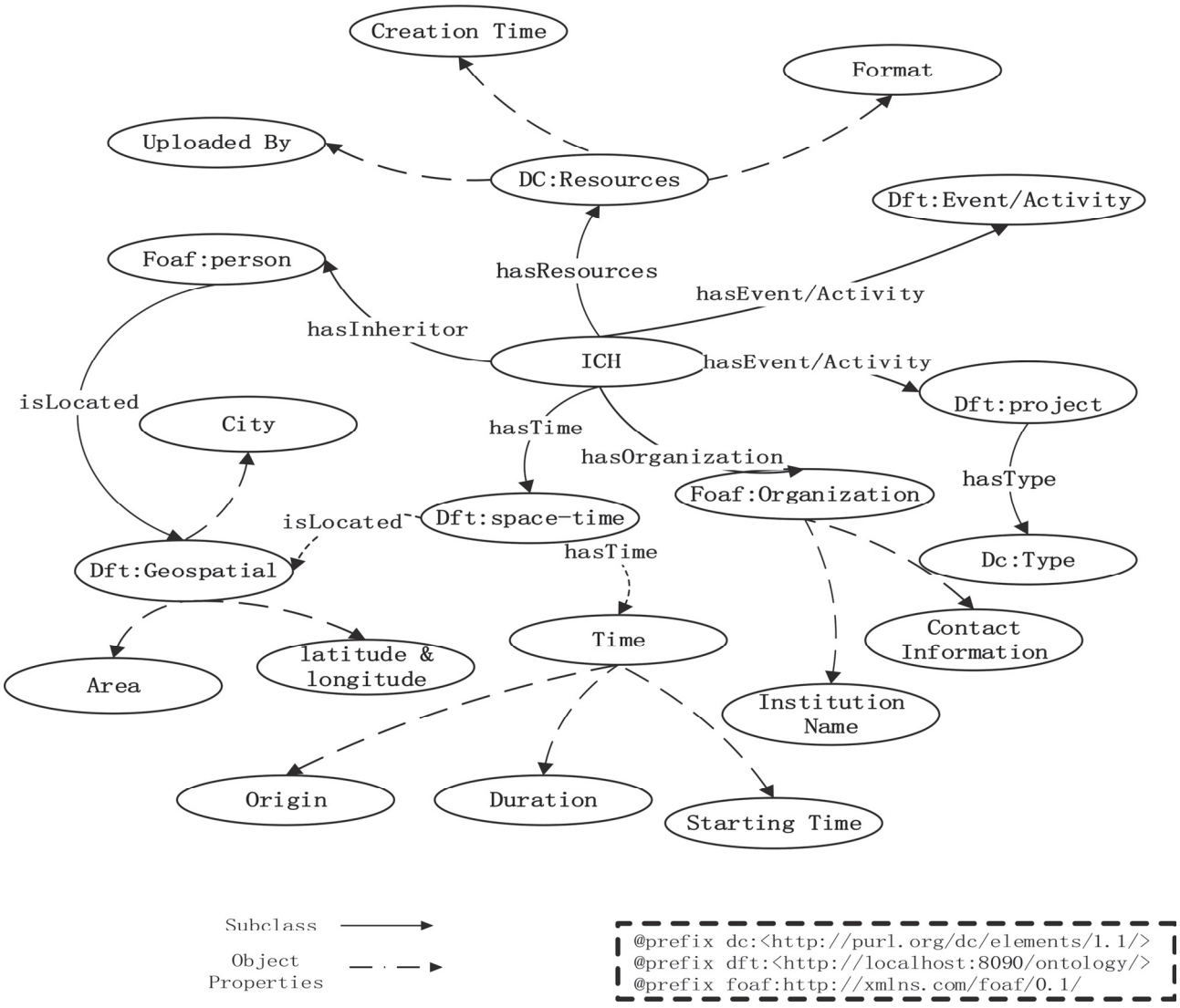

Figure 4. Ontology frame diagram.

4.3 Semantic association

Semantic association is at the core of intangible cultural heritage spatiotemporal data knowledge organization. It is the process of representing, storing, and sharing domain knowledge and revealing the explicit and implicit relationships in intangible cultural heritage knowledge organization through association so that scattered knowledge can form and converge. Therefore, semantic association consists of four parts: semantic mapping, relational mapping, associated data mapping, and associated data publishing.

Semantic mapping refers to the mapping of relational data and ontology. It has two levels: simple mapping and graph-based mapping. The purpose of simple mapping is to realize the relationship between the attribute table in the relational database and the class or attribute in the ontology, while map-based mapping is mapping with the ontology, which is generated based on the graph and is generally described by logical formulas. In the relational model, entities are represented by a two-dimensional table. The columns in the table store entity attributes, and the relationships between entities cannot be described. The internal key in the two-dimensional table stores the entity attributes, and the foreign key stores the relationships between the entities. D2RQ mapping can provide mapping operations and define the mapping rules for converting relational data into RDF triples by standardizing the data structures of two-dimensional tables and the ontology vocabulary. In D2R Server, ClassMap stores ontology classes, and Bridge stores ontology attributes. This section maps the resources of intangible cultural heritage in relational data to data such as inheritors, geographic space, origin, organization, and events.

Relational mapping completes the structural mapping of RDF data according to database-related rules by analyzing relational data. At present, there are two relational mapping methods: (1) directly converting RDF data into SPARQL support format through the relational data library and (2) converting RDF data into RDF documents, which are stored in relational databases. A database that currently supports RDF format is D2R Server. In D2R Server, the RDF format first describes the mapping relationship, and through the mapping relationship, the SPARQL query mode is established, and its data is converted into the RDF triplet format through a query. Second, a relational data service is built so that mapping files can be used to convert the format of spatiotemporal data so that a standard data interface can be formed, which will support access to different types of databases, including D2R Server, SPARQL queries, and URI indices of concatenated data. Based on D2R Server's data association, first, according to the definition of the spatiotemporal data ontology of intangible cultural heritage depending on the ontology class, the attributes of the class of intangible cultural heritage are subjected to semantic and data mapping. Second, intelligent data searches and interactions are realized through the D2R Server platform and SPARQL database language.

Linked data mapping uses the D2RQ platform to access the relational database by creating RDF graphs, converting the relational data into RDF files with mapping, and then completing the data association through D2R Server, allowing users to view the intangible cultural heritage spatiotemporal data through a web browser. In addition, D2R Server can use SPARQL statements to query RDF triples in relational data, and SPARQL statements can encapsulate RDF triples and provide users with visual query results. In this article, the RDF triplet is mapped by establishing a two-dimensional table in the relational database, and the attribute table for the graph mapping of intangible cultural heritage is automatically generated with the help of D2RQ's mapping plugin. D2RQ converts attribute tables in relational databases into RDF triples using mapping language. In the D2RQ platform, d2rq:PropertyBridges converts fields in two-dimensional tables into corresponding object and data attributes, while d2rq:Class Maps converts two-dimensional tables in the database into corresponding ontology classes. Taking projects, time and space, inheritors/related personnel, and events as examples, the mapping of their main relationships is shown in Figure 5.

The linked data are released to describe the intangible cultural heritage spatiotemporal data in RDF mode, form semantic associations, and provide intelligent retrieval and data discovery services on the intelligent application platform to ensure the visual presentation and data sharing of intangible cultural heritage resources in knowledge organization. Linked data publishing provides standardized data access specifications, and its biggest advantage is that it can link data across platforms, establish data links to different data, and facilitate users' data searches from different resource libraries. RDF is a unified standard for the construction of Semantic Web and relational data, and when visualizing digital relationships, it is necessary to convert the class and attribute tables of intangible cultural heritage resources into RDF-structured data, which is key to the release of linked data.

4.4 Knowledge application

The knowledge application of intangible cultural heritage spatiotemporal data is the presentation of unstructured, semi-structured, and structured data resources in the form of RDF descriptions on the web. RDF descriptions express entities in intangible cultural heritage digital resources in the form of RDF triples so that computers can easily read and form associated documents supported by W3C. Visual presentation is used to digitally visualize the knowledge services required by users under the network framework. Intel-

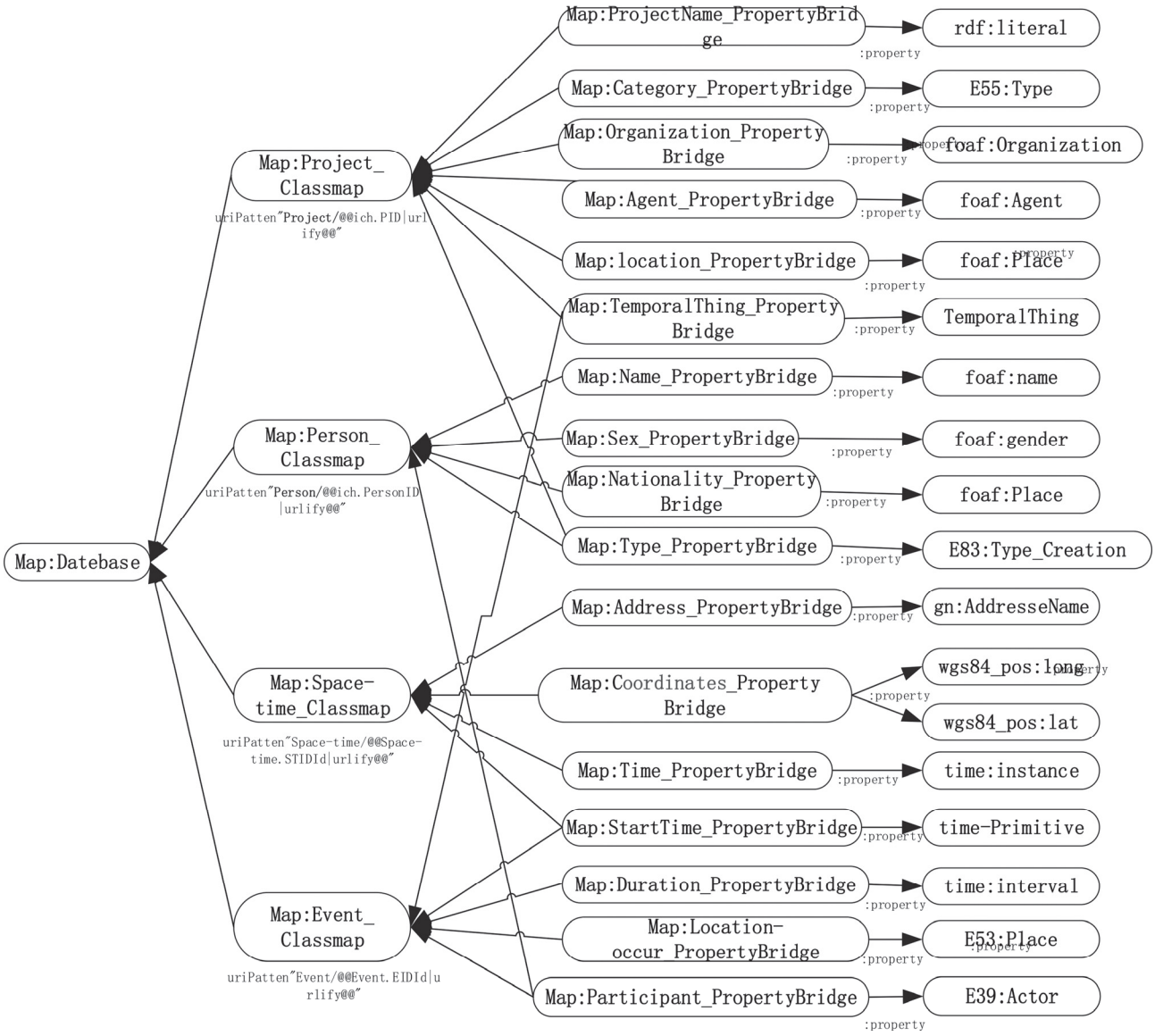

Figure 5. Linked data.

ligent knowledge application involves using semantic association technology to realize RDF description, storage, and sharing of intangible cultural heritage digital resources, and its essence is the process of realizing knowledge base management of intangible cultural heritage digital resources.

5.0 Application Examples of Intangible Cultural Heritage Spatiotemporal Data

5.1 Intangible cultural heritage in Hubei, China

As of December 2021, Hubei, China, has four representative lists of intangible cultural heritage of humanity, 100 national intangible cultural heritage, 347 provincial intangible cultural heritage, 57 representative inheritors of national projects, 571 representative inheritors of provincial projects, and 22 intangible cultural heritage research centers. An analysis of regional spatial characteristics revealed that the distributions of the quantities and structures of intangible cultural heritage in Hubei are uneven, manifesting as dense southern and northern sparseness. The core densities of southwest and southeast Hubei are high, and the spatial distribution densities of their intangible cultural heritage are large. In these two regions, the spatial characteristics of intangible cultural heritage are concentrated and different. Southeast Hubei has many intangible cultural heritage items, with rich types and a dense distribution. However, the number of intangible cultural heritage items in Hubei and southwest Africa is quite large, but the type is relatively single, and the core density is lower than that of southeast

Hubei, mainly traditional dance and traditional music types. Among the top ten types of intangible cultural heritage, Hubei's traditional handcraft skills and traditional music are far more numerous than the other types, and the traditional medicine, traditional sports, and impurity intangible cultural heritage are fewer.

5.2 Visualization of spatiotemporal data of intangible cultural heritage in Hubei, China

Combining the spatiotemporal data of intangible cultural heritage in Hubei reveals that intangible cultural heritage involves many elements in space and time. Based on specific intangible cultural heritage projects combined with related tools, a knowledge map of spatiotemporal data of intangible cultural heritage in Hubei was constructed, as shown in Figure 6. In the graph, nodes represent entity objects related to intangible cultural heritage spatiotemporal data, and edges represent the relationships between entities. The visualization presentation in the knowledge graph shows that the elements involved in spatiotemporal data include people, time, space, and events.

By sorting out the relevant items of intangible cultural heritage in Hubei, China, and selecting the national intangible cultural heritage project Qu Yuan Legend, the spatiotemporal data shown in Figure 7 were obtained. The map

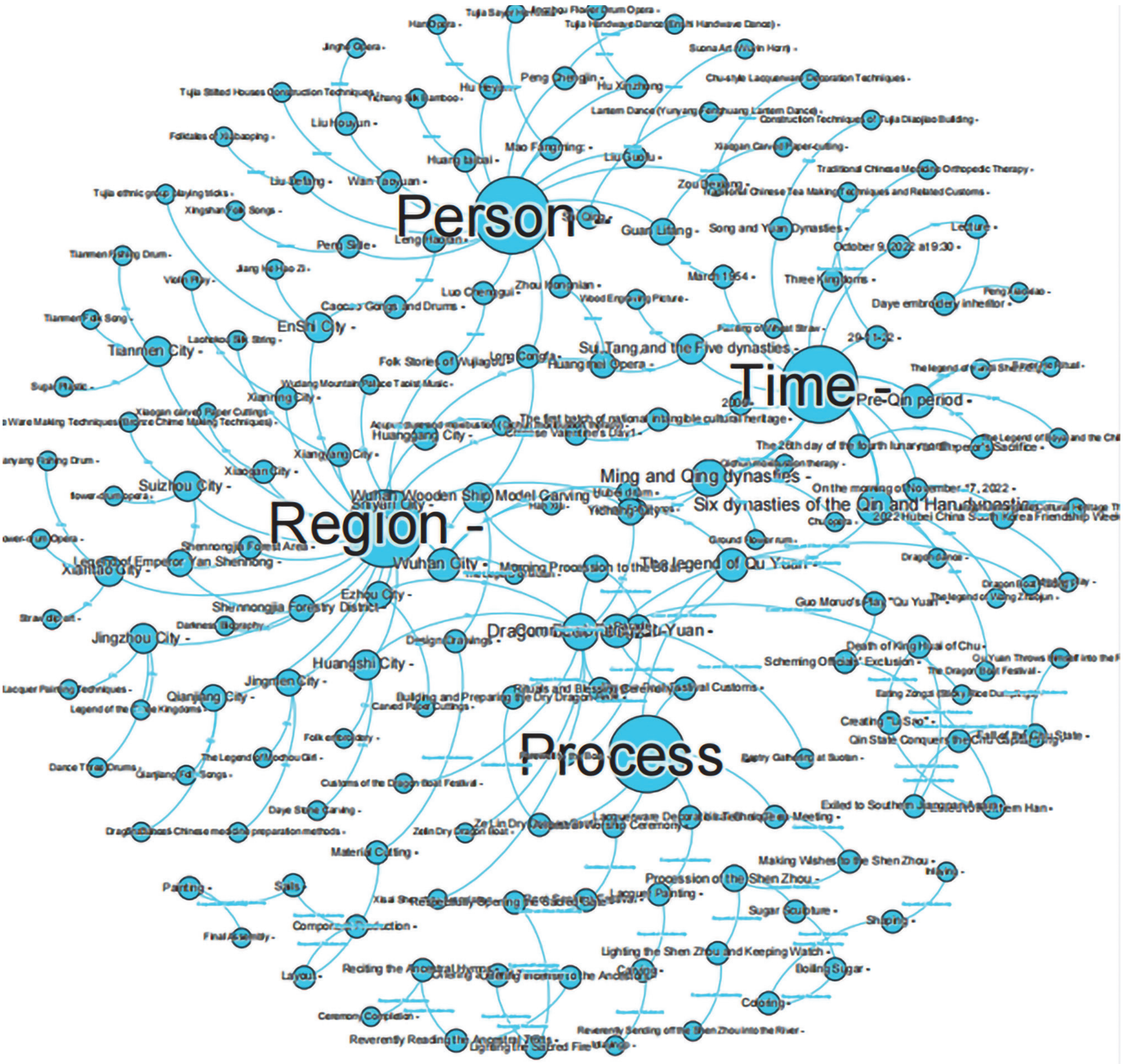

Figure 6. Knowledge map of spatiotemporal data of intangible cultural heritage in Hubei, China.

Figure 7. Visualization of the Qu Yuan Legend Map.

shows the knowledge related to the legend of Qu Yuan. The area to which the legend of Qu Yuan—which originated in the Qin, Han, and Six Dynasties periods—belongs is Yichang City. The relic item is related to the customs of the Dragon Boat Festival, and there are three subevents for commemorating Qu Yuan: Sao Tan Poetry Meeting, Zongzi Eating, and Dragon Boat Race. Knowledge mining of intangible cultural heritage time, space, and related events will help grasp the historical evolution of Hubei's intangible cultural heritage, reveal the law of intangible cultural heritage space and time changes, and discover intangible cultural heritage stories and knowledge. Strong data support.

5.3 Hubei digital resources showcase, China

The ultimate goal of knowledge organization based on web intangible cultural heritage spatiotemporal data is to display intangible cultural heritage resources through user searches visually. This article constructs an intangible cultural heritage digital resource library to form an intangible cultural heritage spatiotemporal data ontology; converts it into RDF-structured data according to concepts, attributes, and relationships; and organizes the RDF knowledge in the resource library to form linked data through Drupal mapping. Professional computer users can directly input SPARQL statements to traverse and search the relational data of intangible cultural heritage digital resources. This professional sentence search makes intangible cultural heritage knowledge services more accurate. General users can search the aforementioned data by entering keywords in the browser's search window. The system's background automatically recognizes, extracts, and divides the user's natural language, converts it into a SPARQL query statement, searches it in the resource library, and automatically searches for topics related to the subject. The resources are aggregated together, and the search results are presented visually to the user through the browser. Taking the Yichang area as an example, the intangible cultural heritage items in this area were inquired about, as shown in Figure 8.

6.0 Conclusion

Focusing on research on the digital resource knowledge organization of intangible cultural heritage spatiotemporal data, this article combines knowledge engineering, informatics, information management, and other forms of interdisciplinary integration. It discusses the process of digital resource knowledge organization and intelligent knowledge services in-depth. The article describes the knowledge organization of intangible cultural heritage spatiotemporal data from bottom to top, which enriches the design and access requirements of domain knowledge ontology, hints at the explicit and implicit relationships of regions, and visually displays the digital resources of intangible cultural heritage spatiotemporal data while improving intelligent knowledge services. Based on the best practices of knowledge organization and semantic description, effective intangible cultural heritage spatiotemporal data knowledge organization is realized, reflecting knowledge services' shareability, discoverability, and reusability in the intelligent era. The research on knowledge organization of intangible cultural heritage spatiotemporal data will accelerate the integration of information resources in the intangible cultural heritage field and the process of knowledge engineering, improving the digital construction of resources and the intelligent acquisition of knowledge.

The knowledge organization of intangible cultural heritage spatiotemporal data has a specialized and subdivided semantic description for research in the field of intangible cultural heritage. Its concepts, attributes, and relationships are mostly derived from the perspective of geospatial information. Knowledge organization of intangible cultural heritage spatiotemporal data, such as items, inheritors, and other elements, is the main object of semantic description, and its application will benefit the granularity of intangible cultural heritage spatiotemporal data description and is conducive to the design and development of digital humanities leadership knowledge organization. Finally, this article reports research conducted only on regional characteristics, ontology construction, and knowledge association. There is only one data source, and the accuracy of the ontology model must be improved. In follow-up research, it is necessary to enrich data

Project	Level	Region	Preview
Traditional Folk Rites in Xiabaoping	National Level	Yichang City	Preview
The riddle of Qinglin Temple	National Level	Yichang City	Preview
Xingshan Folk Songs	National Level	Yichang City	Preview
Yichang Silk Bamboo	National Level	Yichang City	Preview
Zhijiang folk wind and percussion music	National Level	Yichang City	Preview
Tujia Sayer Ho	National Level	Yichang City	Preview
Dragon Boat Festival Customs	National Level	Yichang City	Preview
The legend of Qu Yuan	National Level	Yichang City	Preview
Legend of Wang Zhaojun	National Level	Yichang City	Preview
Folk Stories of Wujiagou	National Level	Yichang City	Preview

Figure 8. Display of intangible cultural heritage resources in Yichang, Hubei.

sources, expand ontology resources, and dig deep into knowledge relationships to enhance the application of digital resources organized by intangible cultural heritage knowledge and to promote the digital protection of intangible cultural heritage and intelligent knowledge services.

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