A Knowledge-based Description Framework for Ancient Chinese Map Documents in the Digital-Intelligence Era and Its Application Scenarios: Postprint

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Abstract

[Purpose/Significance] Ancient Chinese cartographic documents record and bear witness to the glorious continuum of China' s millennia-long civilization and cultural heritage. How to better accomplish their digital preservation, development, and utilization represents an important topic worthy of attention in the field of information resource management. [Method/Process] Following a brief exposition of the cultural connotations and important values of ancient Chinese cartographic documents, this study provides a concise review of the current state of digital research on them, proceeds to design and propose a knowledge-based description framework for ancient Chinese cartographic documents in the digital intelligence era, with separate analyses of its key modules, and an exploration of its typical application scenarios. [Results/Conclusion] The proposed knowledge-based description framework primarily comprises key modules including resource entities, description objects, knowledge abstraction, cartographic representation, and cartographic display, which can provide important theoretical and technical support for the deep integration of associated knowledge among ancient cartographic documents, people, places, times, events, and objects.

Full Text

Preamble

Title: Research on the Knowledge-Based Description Framework and Application Scenarios of Chinese Ancient Map Documents in the Digital Intelligence Era

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Abstract:
[Purpose/Significance] Ancient map documents record and carry the glorious course of Chinese civilization' s continuity and cultural inheritance spanning thousands of years. How to better accomplish their digital preservation and development utilization is an important issue worthy of attention in the current field of information resource management. [Method/Process] Based on a brief exposition of the cultural connotations and important values of ancient map documents, this paper summarizes their current digital research status, then designs and proposes a knowledge-based description framework for Chinese ancient map documents in the digital intelligence era, analyzes its key modules, and explores its typical application scenarios. [Results/Conclusions] The proposed knowledge-based description framework mainly includes key modules such as resource entities, description objects, knowledge abstraction, map expression, and map display, which can provide important theoretical and technical support for the deep integration of associated knowledge among ancient map documents, people, places, time, events, and objects.

Keywords: Digital intelligence era; Ancient map documents; Digital humanities; Knowledge-based description; Historical geographic informatization

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1 Problem Statement

Ancient map documents record and carry the glorious course of Chinese civilization' s continuity and cultural inheritance spanning thousands of years. The rapid development of digital intelligence technologies such as big data, artificial intelligence, and the metaverse has continuously influenced existing research paradigms in the field of information resource management, sparking research fervor in digital humanities and historical geographic informatization. Ancient map documents represent the most unique resource type within ancient books and archival materials. They not only bear the excellent genes of Chinese civilization and outstanding traditional culture that have endured for millennia, but also serve as important carriers for telling Chinese stories, spreading Chinese spirit, and showcasing China' s image. In the context of building a Chinese-characteristic philosophy and social sciences academic system, there is an urgent

need to conduct deeper research on the geographic information, cultural connotations, and civilizational values embedded in Chinese ancient map documents.

The intervention of digital intelligence theories and technologies has broken traditional research paradigms and academic logic for ancient map documents. Currently, digital research on ancient map documents in China mainly concentrates on image digital resource management, historical geographic informatization, and historical GIS issues, where ancient map documents are primarily treated as ancient book image data. However, research on their knowledge organization is relatively scarce, and their rich humanistic connotations and social values have not been adequately explored. The narrative expression and knowledge-based description of heterogeneous information have not received sufficient attention and full demonstration. This paper analyzes the current status of digital research on Chinese ancient map documents, explores the theoretical cognition and conceptual connotations of knowledge-based description for ancient map documents in the digital intelligence era, and proposes a knowledge-based description framework grounded in digital intelligence concepts, elaborating on its application scenarios.

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2 Literature Review

Ancient map documents constitute an important component of Chinese ancient literature, representing ancient ancestors' subjective cognition, expression, exploration, and recording of the objective environment. They primarily employ map languages such as symbols, text, graphics, and lines to locally depict simple geographic spatial information on physical carriers including clay tablets, stone tablets, woodcuts, silk, and paper. Through methods such as landscape painting techniques, the six principles of cartography, grid-based mapping, and triangulation surveying, these documents demonstrate ancient Chinese expression and cognition of the physical world and geographic space.

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3 Knowledge-Based Description Framework for Ancient Map Documents

3.1 Theoretical Analysis

Chinese ancient map documents exist in large quantities with wide distribution. Due to the fragility of their recording carriers, most are sealed in high-standard closed environments. As unique archival documents and historical geographic literature, they have attracted increasing attention from researchers and the public. The value of ancient map documents reflects ancient Chinese state rule intentions and ethnic distribution rather than modern surveying and mapping precision. Having experienced development stages of digital scanning and storage, GIS-based electronic maps, historical atlases, historical geographic

databases, and information systems, they are gradually advancing toward intelligence and knowledge-based stages. Representative service platforms have emerged, including the China Historical Geographic Information System, the Ming and Qing Dynasty Map Database, the Map Digital Archive Integration Query System, and Digital Cartography.

Knowledge-based description of ancient map documents is neither equivalent to traditional digital scanning and storage nor to text conversion after OCR of text-based ancient books—it encompasses both. It requires extracting relevant data and information from ancient map documents, establishing knowledge associations and fusion with related knowledge resources, and undergoing processes of identification, extraction, analysis, organization, association, positioning, and transformation of relevant contextual information. For ancient map documents, the temporal, spatial, and contextual information and scenarios they contain are particularly important. Temporal information includes relevant temporal dimensions such as dynasties, reign titles, and sexagenary cycles. Spatial information is relatively complex, including geographic, location, and place name information, as well as social and humanistic spaces. Human information mainly includes various types of people involved, such as organizers, drawers, recorders, and first collectors. Event information primarily includes various historical events, activities, and processes related to them. Object information mainly includes valuable image carriers related to them.

3.2 Knowledge-Based Description Framework

Influenced by factors such as thinking perspectives and technical methods, the production and use of ancient map documents existed within a relatively closed system. Most ancient map documents could only achieve static depiction and planar representation of geographic spatial objects within limited carrier description ranges. The knowledge-based description of ancient map documents in the digital intelligence era requires comprehensive mastery of all entities, elements, and knowledge related to them, achieving cross-domain knowledge organization and integration centered on their geographic spatial information (such as place names, divisions, and locations), involving the identification, positioning, and transformation of relevant contextual information. This necessitates continuous expansion of existing theoretical and technical frameworks.

From the perspective of digital intelligence theory systems and digital humanities technologies, this paper designs and proposes a corresponding knowledge-based description framework as shown in [Figure 1: see original paper]. The framework clarifies key modules including resource entities, description objects, knowledge abstraction, map expression, and map display for ancient map documents.

3.3 Resource Entities and Description Objects

The resource entities of Chinese ancient map documents form the foundation of their knowledge-based description. They are precious materials through which ancient Chinese ancestors understood, recorded, and mastered the world. Their classification system has evolved from early three-category, regional, and thematic classifications to modern content-based classification methods including territory, urban, river engineering, water conservancy, mountains and rivers, and military maps. The intervention of digital intelligence theory and technology has expanded the object space of ancient map documents from traditional binary space to a multi-dimensional space composed of geographic space, humanistic space, information space, and technological space.

Geographic space forms the basis for expression and description of ancient map documents. Description objects can be elaborated from both macro and micro levels. The macro level includes overall divisions, oceanic circles, and other physical geographic spatial entities, while the micro level includes descriptions of place names, geometry, and spatial information. Humanistic space mainly includes the historical spatial contexts depicted in ancient map documents. Information space primarily involves the internet, knowledge bases, and virtual spaces related to digital intelligence computing, knowledge-based association, and visualization display. Technological space mainly involves big data, artificial intelligence, digital humanities, and geographic information systems related to knowledge-based description.

Knowledge-based description of ancient map documents needs to address three key issues: first, extracting relevant temporal, spatial, relationship, and specific attribute information from ancient map documents; second, establishing precise mapping relationships based on existing temporal, spatial, and relationship vocabularies and conversion tools; and third, establishing a knowledge-based description framework for Chinese ancient map documents in the digital intelligence era to effectively organize and associate related ancient map documents with knowledge resources such as people, places, time, events, and objects.

3.4 Knowledge Abstraction

Knowledge abstraction refers to the process of extracting specific entities, features, or relationships from ancient map documents, discarding elements with weak relevance to the research theme, and 挖掘 ing and presenting common patterns and shared knowledge around the research theme. Describing complex geographic, humanistic, information, and technological multi-space objects in the form of ancient map documents is itself a process of knowledge abstraction. The knowledge abstraction of ancient map documents in the digital intelligence era mainly involves four aspects: time, space, attributes, and elements.

3.4.1 Temporal Abstraction Temporal abstraction records and describes the drawing, preservation, and utilization time of ancient map documents, in-

cluding both historical time and real time. Historical time involves dynasties, reign titles, and Gregorian calendar years, such as the *Kunyu Wanguo Quantu* presented by Italian missionary Matteo Ricci to the Wanli Emperor in 1602. Real time refers to the actual collection, management, and utilization time in the real world, such as November 12, 2023, when the Nanjing Museum exhibited the *Kunyu Wanguo Quantu* during its 90th anniversary special exhibition. The intervention of digital intelligence technology enhances the freedom, integration, and continuity of historical time description in ancient map documents.

3.4.2 Spatial Abstraction The uniqueness of ancient map documents lies in their demonstration of not only immediate records of specific place names but also multiple records of the same place name across different eras in related map documents or ancient books. The same place name may have different geographic presentations and spatial records in different dynasties due to administrative division changes or drawer cognitive differences. Spatial abstraction of ancient map documents must consider the knowledge-based abstraction and description of related geographic information, including spatial location descriptions of place names, topological relationships, and geometric outlines.

3.4.3 Attribute Abstraction The human, geographic, and other entity resources involved in ancient map documents possess rich quantitative and qualitative attribute features. Objects in information space and technological space can be assigned certain attribute values based on specific description themes or rules. The rapid development of digital intelligence technology has enhanced the information description capability and knowledge expression ability of ancient map documents, enabling attribute interaction and fusion across different temporal, spatial, granular, and contextual dimensions, which can reflect the multi-fusion characteristics of ancient map documents and their entity resources.

3.4.4 Element Abstraction Element abstraction primarily describes and expresses the five elements of people, places, times, events, and objects involved in ancient map documents. It includes drawers, first collectors, recorders, and related personnel; place names and divisions recorded in or related to ancient map documents; temporal elements such as reign titles, sexagenary cycles, and Gregorian years; historical events, behaviors, or processes related to ancient map documents; and items related to recording and utilizing ancient map documents.

3.5 Ancient Map Expression

Ancient map expression mainly focuses on temporal structure, spatial organization, spatial dimensions, and expression granularity. In terms of temporal structure, based on temporal expression differences, ancient map document content can be organized according to specific temporal expression rules or requirements, forming linear, branching, and cyclic structures. Spatial organization employs vector data organization and raster data organization as two spatial

organization methods. Spatial dimensions have expanded from traditional two-dimensional space to three-dimensional, four-dimensional, and even higher dimensions through digital intelligence theory and technology. Expression granularity is divided into coarse, medium, and fine levels, which can provide professional knowledge-based description according to different user needs for specific events or themes.

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4 Application Scenarios of the Knowledge-Based Description Framework

Although digital intelligence theory and technology have demonstrated enormous application potential in the digital preservation and development of ancient book documents, knowledge-based description application practices for Chinese ancient map documents remain relatively scarce. This section explores several typical application scenarios using the *Wanli Coastal Defense Map* drawn in Volume 8 of *Zheng Kaiyang' s Miscellaneous Works* as an example.

4.1 Automatic Q&A Service for Ancient Map Document Knowledge

The constructed knowledge-based description framework can automatically identify, abstract, and express the content of relevant ancient map documents, effectively organizing related place names and knowledge resources to provide professional automatic Q&A services about ancient map document knowledge for different types of users.

4.2 Intelligent Construction Service for South China Sea Rights Protection Evidence Chain

The *Wanli Coastal Defense Map* depicts coastal mountains and rivers during China' s Ming Dynasty period, marking Chinese islands in the South China Sea such as Diaoyu Island and Huangwei Island, providing important documentary support for China' s South China Sea rights protection. The knowledge-based description framework can establish an intelligent service system for the South China Sea rights protection evidence chain across multiple dimensions including temporal sequences, spatial locations, and fine granularity, providing important data, documentation, and service support.

4.3 Interactive Narrative Service for Ancient Map Documents

Interactive narrative represents one of the most typical application scenarios of digital intelligence theory and technology. The constructed knowledge-based description framework can effectively integrate all ancient map documents, historical geographic information, social and humanistic information, and excellent traditional culture and connotation values. By identifying and extracting relevant content elements from ancient map documents around specific themes,

it can build a multi-user collaborative interactive narrative service, providing users with immersive experiences through interactive methods.

[Figure 2: see original paper] Volume 8 of Zheng Kaiyang's Miscellaneous Works: "The Map of Coastal Defense for Ten Thousand Miles" (partial)

5 Conclusion

Chinese ancient map documents record and carry the glorious course of Chinese civilization' s continuity and cultural inheritance spanning thousands of years. How to better accomplish their digital preservation and development utilization, and deeply 挖掘 their rich cultural connotations and civilizational values, is an important issue worthy of attention in the current field of information resource management. This paper designs and proposes a knowledge-based description framework for Chinese ancient map documents in the digital intelligence era from the perspective of digital intelligence theory systems and digital humanities technologies, analyzes its key modules including resource entities, description objects, knowledge abstraction, and map expression, and explores its typical application scenarios. The proposed framework can provide important theoretical and technical support for the deep integration of associated knowledge among ancient map documents, people, places, time, events, and objects.

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Note: Figure translations are in progress. See original paper for figures.