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Cultural Arts Research and Development

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ARTICLE

Integrating GraphRAG and GIS for Cultural Heritage Digitization: A Case Study of Jiangbei District

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ABSTRACT

With the rapid advancement of digital technologies, the preservation and management of cultural heritage face both new opportunities and challenges. Jiangbei District in Ningbo, Zhejiang Province, is home to a substantial number of immovable cultural relics requiring systematic documentation and scientific oversight. In response to the Fourth National Cultural Relics Survey, this study proposes a data-driven approach to support the digital management and sustainable use of these resources.The research adopts a structured methodology encompassing data collection, organization, analysis, and exploration. Through the curation of both historical and newly acquired records—including combing, cleaning, and filtering—a complete framework was developed. Based on this, a digital platform was constructed to integrate, manage, and visualize cultural heritage data.Visualization techniques were employed to present the spatial distribution and associative characteristics of heritage sites, facilitating intuitive understanding and enhancing decision-making capabilities. The resulting platform supports structured data management, enabling more effective cultural relic protection, knowledge inheritance, and cross-sectoral application.Beyond technical outcomes, the platform also contributes to public engagement and education by improving accessibility and promoting awareness of cultural heritage. This broader societal impact supports not only the long-term preservation of local culture but also encourages community involvement and cultural literacy.Overall, this study lays a foundation for the digital transformation of cultural heritage work in Jiangbei District and offers a replicable model for other regions seeking to combine heritage protection with modern digital methodologies. It provides both a practical management tool and a reference for interdisciplinary research and heritage-based development initiatives.

Keywords: Digital Humanities; The Fourth Census of Cultural Relics; Database; Data Visualization

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ARTICLE INFO

Received: 11 March 2025 | Revised: 16 April 2025 | Accepted: 26 April 2025 | Published Online: 1 June 2025

DOI: https://doi.org/10.55121/card.v5i1.336

CITATION

Xu, M., Jia, W., 2025. Integrating GraphRAG and GIS for Cultural Heritage Digitization: A Case Study of Jiangbei District. Cultural Arts Research and Development. 5(1): 50–63. DOI: https://doi.org/10.55121/card.v5i1.336

1. Introduction

1.1. Background and Motivation

The census of cultural relics is an essential foundational work for the advancement of the field of cultural relics, constituting a substantial national survey. The census provides a comprehensive overview of China's immovable cultural relics resources, facilitating precise assessments of the status of cultural relics protection. It also enables the scientific development of cultural relics protection policy, to enhance the protection of cultural relics and cultural heritage. Furthermore, it contributes to the reinforcement of the protection of historical and cultural heritage in urban and rural areas, fostering cultural self-confidence and underpinning the construction of a robust socialist cultural power. The census holds significant, far-reaching implications for these objectives [1].

The digitalization and information management of cultural heritage has become a significant development trend in the realm of heritage protection and utilization. Cultural heritage is an integral component of national soft power, serving not only as a repository of historical memory but also as a crucial asset in the formation of urban cultural identity and the promotion of sustainable development. The digitization of cultural heritage has been identified as a pivotal element in achieving the overarching objective of "development under protection and protection under development." This approach is recognized as a critical component of the broader strategy aimed at fostering a robust cultural milieu. In the context of China's accelerated urbanization and technological progress, the urgent need to address the challenges of scientific, accurate, and visualized cultural heritage protection and management has become a pressing concern [2].

A substantial corpus of research, including both published papers in academic journals and field research data, has demonstrated the significant role of cultural heritage digitization in the protection, inheritance, and development of cultural heritage. The Charter on the Preservation of Digital Heritage, adopted by the United Nations Educational, Social and Cultural Organization (UNESCO) on October 15, 2003, underscores the imperative to preserve and maintain "cultural heritage, including digital heritage." The term "preservation" is understood to encompass resources pertaining to culture, education, science, administration, and information regarding technology, law, medicine, and other disciplines. The digital heritage of China is of significant importance for the preservation and development of cultural heritage [3]. Liu Fang of the National Museum of China Research Institute pointed out that tangible cultural heritage not only plays multiple roles as a carrier of historical inheritance, a source of cultural innovation, a driving force for economic development, a cornerstone of social identity, and a bridge for international exchanges, but digital narratives can provide audiences with a new perspective for understanding and appreciating tangible cultural heritage [4]. In recent years, with the rising demand for discovering the cultural value of heritage and the challenges of heritage preservation brought about by climate change, greenhouse gas emissions, natural disasters, and human destruction, heritage digitization has become an important trend and field of contemporary heritage research and practice [5]. Fragmented heritage data can be transformed into knowledge that supports heritage decision-making through information integration, thus enhancing the efficiency of heritage information utilization and reflecting heritage values more profoundly [6]. Therefore the construction of digital models and heritage databases implies that all heritage data can be organized, stored and managed in the form of databases, and that the unification of data structures, standardization of data formats, and specification of data use will greatly enhance the efficiency of heritage information utilization, while facilitating the further discovery, categorization, storage and sharing of heritage information for people now or in the future [7].

Despite the ongoing updates and advancements in digitization technology for cultural heritage, as well as the continuous standardization of this process, the digitization of immovable cultural heritage remains slow. This is due to a lack of research in this area, a limited scope in database development, and a restricted application of data. Consequently, the full value of digitization is not realized [8]. As a significant conduit of history and culture, immovable cultural relics serve as a record of social development, architectural art, and cultural skills across different periods. The uniqueness and non-renewability of these relics bestow upon them a high historical value. However, due to the alterations in the natural environment and the esca-

lation of human activities, numerous immovable cultural relics are confronted with varying degrees of deterioration. For instance, natural factors such as weathering, environmental pollution, and earthquakes have the potential to damage cultural relics. Additionally, modern engineering construction and urbanization can lead to changes in the environment where cultural relics are located, or even pose a direct threat to their survival. These factors contribute to the gradual loss of the material form and cultural information of cultural relics, thereby jeopardizing the integrity of their cultural heritage. In this context, the application of digital technology to cultural relics is of particular importance. The digitization of immovable cultural relics is important for two reasons. First, it serves as a means of protecting historical information. Second, it is a modern tool for the continuation and transmission of cultural values [9]. The integration of technology and culture has led to the development of knowledge extraction and knowledge graph construction methods that are specifically tailored to Chinese cultural relics. These methods have the potential to mitigate the loss of value associated with cultural relics and to offer novel approaches for safeguarding and perpetuating history and culture [10].

Compared with the previous three cultural relics censuses, the ongoing fourth cultural relics census has achieved leapfrog progress in terms of technical means, data management, census scope, publicity, and legal system construction, further promoting the combination of cultural relics protection and social participation, and is an important step towards systematizing and data-driven management of Chinese cultural relics. However, due to the lack of effective data integration and visualization means, the large amount of data generated by the census often presents problems such as fragmentation, static, and low utilization rate.

1.2. Problem Statement

Given the current cultural heritage database and visualization research exists in the methodological inconsistency, regional adaptability is insufficient, and other problems, this paper, before launching the empirical research, first of all, review and comment on the existing literature, to clarify the current status of the research and the problems to be solved:

In terms of the significance of cultural heritage digital inheritance, Liu Mingzhen and Li Yuanxu take cultural relics digital cultural inheritance as the research object, sort out its dissemination mechanism, and point out that the four dimensions of technology, market, culture, and society are interdependent and mutually reinforcing in cultural heritage digital inheritance, which jointly promote the process of cultural heritage protection, inheritance, and development [11]. Sun Hui believes that the results of the computational layer in the framework of digital humanities research can quickly give an overview of the massive amount of literature, vein or all kinds of correlation, to realize the so-called “remote reading”, and play the role of a “telescope” or even a “microscope”. Microscope” role [12]. Fu Yu, Li Boran, and Xu Congjun proposed a “two-layer effect” analysis framework of the elements and influence mechanisms of digital development and dissemination of cultural resources from the perspective of digital humanities, focusing on the deep effect of public perception of cultural confidence, and improving the methodology from the three phases of cultural information analysis, which provides an effective reference example for more research in the field of cultural digitization. The methodology is improved from the three stages of cultural information analysis, which provides an effective reference for more research in the field of cultural digitization [13].

In terms of information collection technology for immovable cultural relics, the Dunhuang Academy has been exploring digital conservation since 1993. Chen Zhenwang, Fan Jinshi, Fu Xinyi, Ma Xiaojuan, Sun Zhijun, and others have researched digitalization to mitigate the natural loss caused by human interference [14-15]. Shuang Xihong and Pan Guangfan took the immovable cultural heritage rock paintings as the research object, and put forward the digital collection, digital development of rock painting resources, digital Internet of Things technology to improve the environment of rock paintings, as well as digital monitoring to realize the multi-dimensional observation of cultural heritage digital humanities protection path [16].

In terms of database construction, Li Zhangchao and He Lin studied the progress of semantic organization of China’s cultural heritage, sorted out the topics, data sources, and stages experienced by the current semantic organization of cultural heritage, and pointed out that se-

mantic organization of cultural heritage currently exists in the problems of data interoperability, standardization of ontology, multi-language knowledge expression, personalized semantics, construction of automated tools, and data copyright issues [17]. Dou Peng takes Qinling Great Cultural Resource Base as the research object and proposes database construction principles and content framework from the perspective of digital empowerment [18].

In the practice of digital humanities, Zhang Mu, Guo Zhen took Chaozhou, Guangdong as an example, used Citespace tools to draw the knowledge map of Chaozhou non-legacy digitization as a way to clarify the research dynamics of the academic community, and utilized the corpus methodology to analyze the content of media publicity in terms of high-frequency words, indexing lines, collocations, and so on, and explored an effective path of digital dissemination [19]. Haoxian Wang, Ziming Zhou, Feifei Ding, Chengfu Wei carried out the practice and exploration of the integration of digital humanities and big language model to promote the retrieval of ancient literature in the field of ancient literature, the standardized metadata organization, metadata extension supported by the big model, the support of natural linguistic search terms, fault-tolerant retrieval mechanism, vector engine efficient retrieval, etc., to promote the digital transformation of libraries, optimize the efficiency of information retrieval and accuracy [20].

While existing studies provide a solid theoretical and methodological foundation for this research, they also present notable limitations. Most research predominantly focuses on the national or provincial level, leaving the construction and visualization of regional databases—especially at the urban, district, and county levels—relatively underdeveloped. Additionally, the majority of cultural heritage digitization research emphasizes intangible cultural heritage, with limited studies and practical applications addressing tangible cultural heritage.

Current research on cultural heritage databases and visualization also faces several challenges, particularly regarding methodological inconsistency and limited regional adaptability. Traditional databases often lack standardized data structures, making cross-regional data integration challenging. Furthermore, many existing systems are not well-suited to accommodate the diverse and dynamic characteristics of local cultural heritage, resulting in data fragmentation and low utilization.

In the practice of digital humanities, various tools and techniques have been employed to enhance data visualization and dissemination. For example, CiteSpace has been utilized to create knowledge maps and analyze research trends in the field of intangible cultural heritage digitization, while digital conservation methods have been explored to mitigate the deterioration of tangible cultural heritage, as seen in studies on the Dunhuang murals.

Despite the effectiveness of these methods in their respective contexts, they primarily focus on visualizing research trends or digital preservation of tangible cultural heritage. In contrast, the GraphRAG technology introduced in this study addresses a different challenge: relational reasoning and the processing of unstructured text in regional cultural heritage databases. Unlike CiteSpace, which is mainly used for knowledge mapping and literature analysis, GraphRAG constructs knowledge graphs that dynamically organize data and support semantic associations. Unlike traditional digitization methods focusing on preservation, GraphRAG excels at integrating complex relationships within heterogeneous data, offering a more structured and accessible data framework.

To address these issues, this study introduces GraphRAG technology, which excels in relational reasoning and handling unstructured text. Unlike traditional relational databases that require rigid schemas, GraphRAG efficiently organizes data through knowledge graphs, enabling dynamic updates and semantic associations. Its ability to automatically extract entities and relationships from textual data greatly enhances data structuring and accessibility. This innovative approach addresses the challenges of data inconsistency and poor adaptability in existing heritage management systems.

1.3. Research Objectives and Questions

As one of the central urban areas, Jiangbei District in Ningbo City has rich cultural heritage resources, including ancient ruins, historical buildings, and industrial remains. However, these resources have long faced problems of data redundancy, low digitization, and insufficient public participation in the management process. To effectively address these challenges, there is an urgent need to establish a centralized, structured, and user-friendly cultural heritage

database, accompanied by an efficient data visualization strategy, to enhance the accessibility, analytics, and social communication of the resources.

Based on the data of the Fourth National Cultural Relics Census and focusing on the Jiangbei District of Ningbo City, this study explores the construction of a regional cultural heritage database and the realization path of data visualization. The research objectives include: (1) collecting, standardizing and integrating cultural heritage data in Jiangbei District; (2) designing and constructing a relational database that supports multi-dimensional querying and dynamic updating; and (3) developing a visualization tool to demonstrate the spatial distribution and category characteristics of cultural heritage and to assist in decision-making and public awareness. Through the above work, this paper tries to establish a localized digital management model of cultural heritage and provide theoretical and practical references for urban cultural governance.

2. Materials and Methods

2.1. Data Source and Collection

The data used in this study mainly come from the Fourth National Cultural Relics Census organized and implemented by the State Administration of Cultural Heritage, which systematically records the immovable cultural relics resources within the scope of Jiangbei District of Ningbo City, and the data covers basic attributes such as the name of the relics, their categories, geographic location, historical period, protection level, and description of their current status.

To make up for the problems of missing spatial information or inconsistent attribute standards in the census data, the research team carried out field surveys and data review work in conjunction with the cultural heritage management department of Jiangbei District. The coordinate information and image data of some cultural relics were supplemented through field shooting, positioning, and visiting to improve the accuracy and completeness of the data. The specific content includes:

1. Field research and text recording

For each immovable cultural relic, detailed records are made by unified standards, covering the following information:

- Basic information of cultural relics: clear identification of cultural relics, including name, category, age, protection level, street, and community to which it belongs, to facilitate classification and management;
- Description of the cultural relics monolith: record the architectural structure of the cultural relics.
- Description of the preservation status of cultural relics: record the integrity of the current cultural relics and the existence of signs of damage;
- Cause of damage to cultural relics: analyze the impact of natural factors and human activities on cultural relics;
- Description of the environment in which the cultural relics are located, including the geographical environment and climate conditions around the cultural relics;
- Description of the community environment where the cultural relics are located: describe the social environment, attitude of residents, and related cultural activities of the community where the cultural relics are located.

2. Expert interviews and in-depth processing of information

Invite experts in cultural relics protection to review and supplement the textual information collected by the research team, and dig deeper into the historical value of cultural relics and protection suggestions. Through interviews, experts' professional opinions on heritage protection and restoration are collected and refined into important content in the database.

Through the above strategies, a scientific database is formed with field data as the core and expert opinions as the supplement.

2.2. Data Preprocessing

Before the construction of the database, the original data were first cleaned and standardized, mainly including the following steps:

- Attribute specification unification: unified coding and naming of fields such as cultural relics type, age of belonging, name of administrative region, etc., to eliminate information redundancy and ambiguity; based on the characteristics of the existing

data of immovable cultural relics in Jiangbei District, constructing a path of standardization of data in Jiangbei District through expert interviews and reference to the existing mature cultural heritage common ontology (CIDOC CRM [21]);

- Spatial positioning processing: geocoding of cultural relics using GIS software and satellite images to supplement and correct missing or wrong spatial coordinates;
- Duplicate record rejection: for possible missing values and outliers in the dataset, the data distribution of each variable was comprehensively checked. For random missing values, the mean interpolation method was used to fill them in; for systematic missing values by analyzing the logical relationship between the variables, speculative completions were made by combining domain knowledge; and box-and-line plot analysis was used to locate outliers and take appropriate treatment according to their impact on the analysis, including correction or deletion of extreme outliers. To achieve data consistency and standardization, the study recoded categorical variables to ensure that all categorical variables were defined and coded in a manner consistent with the analysis objectives.

2.3. Database Construction

In the course of establishing a database of immovable cultural relics, it is imperative to take into account the distinctive attributes of cultural relics. This approach is instrumental in addressing the following issues:

Initially, there is a necessity for text data standardization and accurate extraction. Given the predominance of textual documentation in the realm of immovable cultural relics, it becomes imperative to establish a unified data specification. Such a specification would serve to ensure the consistency and accuracy of the information recorded. The implementation of natural language processing technology has been demonstrated to enhance data processing efficiency, thereby establishing a dependable foundation for subsequent analysis [22-23].

In the second phase, the design of the template and the construction of the column framework are undertaken. In accordance with the attributes of immovable cultural relics, the design of a database template is to be undertaken, encompassing fundamental information, historical background, present circumstances, protective measures, and ancillary dimensions. The construction of a scientific and reasonable column framework is imperative for the purpose of supporting the entry and management of comprehensive information in various forms, including text, pictures, sound, image, video, and network new media.

Thirdly, geospatial information and dynamic updates are imperative. Immovable cultural relics are characterized by their specific geographic location attributes; therefore, it is imperative to incorporate geographic information system (GIS) functionality within the database. The construction of the database necessitates the integration of a geographic information system (GIS), which is required to record the precise geographic location of cultural relics and visualize the spatial distribution of cultural relics [24]. Furthermore, the database should be equipped with the functionality to facilitate the real-time update of the current status of cultural relics, repair records, and environmental changes, among other pertinent metrics. This capacity to adapt to the evolving requirements of protection and management over extended periods is paramount.

Fourthly, the equilibrium between public education and professional research is imperative. The database should serve two primary functions: first, to facilitate research and the protection of cultural relics, and second, to fulfill a public education role. The objective is to design an intuitive, interactive interface that offers virtual tours, interactive maps, and other functions [25]. The goal is to enable the public to understand and appreciate the charm of cultural relics. Concurrently, advanced search and data analysis capabilities should be supported to meet the needs of professional users.

The fifth component of the system is effect evaluation and function optimization. Subsequent to database construction, it is imperative to assess the data integrity and system stability through multiple rounds of audit and functional testing. Thereafter, the functions should be continuously optimized based on user feedback and actual needs, with the objective of enhancing the practicality of the database and user experience.

This study adopts MySQL, a relational database

management system (RDBMS), to design and construct the cultural heritage database. The choice of MySQL is driven by its high performance, scalability, and robust data management capabilities, which are particularly well-suited for handling large volumes of cultural heritage data.

To ensure modularity and data organization, the database adopts a modular structure comprising the following core data tables:

- Basic Information Table: Records essential information about cultural relics, including unique identifier, name, category, address, and protection level. This table serves as the primary entry point for querying cultural heritage data.
- Geographic Coordinates Table: Stores latitude, longitude, and spatial reference number. This structure facilitates geospatial analysis and visual representation of heritage sites.
- Historical Staging Table: Maintains historical period data and corresponding time ranges, linking relics to specific historical stages for temporal analysis.
- Multimedia Data Table: Contains associated multimedia resources, such as cultural relic photographs, field collection images, related documents, and other digital files, providing comprehensive support for multimedia data management.

To enhance the system's performance and scalability, the database is configured with primary and foreign key relationships to maintain data integrity and consistency. Additionally, an indexing mechanism is implemented to support cross-table linkage queries, significantly reducing query response time and optimizing data retrieval efficiency.

By utilizing MySQL's modular design and efficient data management, the constructed cultural heritage database not only supports real-time data access and complex relational queries but also ensures data consistency and integrity, addressing the challenges of large-scale cultural heritage information management.

2.4. Knowledge Extraction Process of Cultural Heritage Based on GraphRAG

Semantic reasoning refers to the ability of a system to infer and establish meaningful relationships between concepts, entities, and their attributes by interpreting unstructured or semi-structured data. In the context of cultural heritage data processing, this involves identifying and linking relevant information across heterogeneous datasets to construct a coherent knowledge framework.

To further enhance the semantic structuring level and knowledge service capability of cultural heritage data, this paper introduces GraphRAG (Graph-based Retrieval Enhancement Generation) technology for knowledge extraction and semantic enhancement modeling of cultural heritage textual data.

GraphRAG is a knowledge graph-based retrieval enhancement generation technology that enhances traditional retrieval enhancement generation (RAG) systems by combining knowledge graphs generated from large-scale language models (LLMs). GraphRAG technology utilizes knowledge graphs to integrate entity, relationship, and document graphs to achieve tasks such as fast retrieval, classification, and prediction of graph data [21]. As a form of knowledge organization, knowledge graphs effectively integrate information in the form of graphs, which can help solve the problems caused by information clutter and disorder [26]. The core principle lies in the use of deep learning models to encode the graph data and extract the feature information of the nodes and edges in the graph, which provides a strong support for the subsequent data analysis.

2.4.1. Technical Principle and Process Design

GraphRAG combines structured retrieval (Graph Retrieval) and language generation (Language Generation) mechanisms, and its basic process includes:

1. Corpus preparation: organizing text resources such as cultural relics census forms, field records, and local records;

2. Entity identification and relationship extraction: using natural language processing technology to identify core entities and semantic relationships;

3. Building ontology structure: defining cultural relic types, attributes, and interrelationships based on domain knowledge;

4. Graph building and enhancement: building a knowledge graph and combining it with semantic retrieval algorithms to enhance the reasoning capability;

5. Q&A and generation interface: support natural

language queries and answer generation with the help of a language model.

2.4.2. Application Scenarios and Functional Realization

The research deploys the GraphRAG process to:

- Automatically extract structured information such as time, space, use, protection level, etc. from the text of cultural relics;
- Establish semantic association relations and form knowledge networks;
- Support complex queries and fuzzy Q&A;
- Provide structured knowledge labels for map interface display and linkage.

3. Results

3.1. Database Construction Results

According to the Notice on Guidelines for the Identification of Immovable Cultural Relics (for Trial Implementation) issued by the State Administration of Cultural Heritage [27], the team carried out field research and collection in 2024 in Jiangbei District, Ningbo, and classified the immovable cultural relics collected according to the six categories of ancient buildings, ancient burials, ancient sites, important historical sites and representative buildings in recent times, grottoes, temples, and rock carvings, and other categories. According to the results of field research and collection, Jiangbei District found a total of 249 immovable cultural relics, including 148 ancient buildings, 3 ancient tombs, 12 ancient ruins, 83 modern important historical sites and representative buildings, 1 grotto temples and stone carvings, and 1 other cultural relics that can not be categorized.

Subdivided by the age of the cultural relics, the immovable cultural relics in Jiangbei District span from the Eastern Han Dynasty to the Republic of China period, with the earliest immovable cultural relics being three ancient sites of the Eastern Han Dynasty and the latest recorded until the founding of the country in 1949. Most of the immovable cultural relics are concentrated in the Qing Dynasty and the Republic of China, in which the immovable cultural relics of the Republic of China period are mainly important historical sites and representative buildings of the modern era, including 62 modern buildings; the immovable cultural relics of the Qing Dynasty are mainly ancient buildings, including 120 ancient buildings.

From the geographical distribution of immovable cultural relics, Cicheng Town has the largest number of immovable cultural relics, amounting to 114, including 83 ancient buildings, 3 ancient tombs, 9 ancient ruins, 17 important historical sites and representative buildings of the modern era, 1 grotto temple and stone carvings, and 1 other cultural relics that cannot be classified. Bund Street is in the second place, totaling 54 sites, including 52 important historical sites and representative buildings of modern times, and 2 ancient buildings. Zhuangqiao Street is in the third place, a total of 37, mainly ancient buildings, 29, but also contains an ancient site, important historical sites, and representative buildings of modern times 7. Hongtang Street is in the fourth place, including 18 ancient buildings, an ancient site 1, modern important historical sites, and representative buildings 4, totaling 23 immovable cultural relics. Qianjiang Street is in the fifth place, including 15 ancient buildings, 2 important historical sites, and representative buildings of modern times, totaling 17. Kongpu Street and Wenjiao Street are tied for sixth place, including 1 ancient building in Kongpu Street and 1 important historical site and representative building in modern times in Wenjiao Street. The others also contain one ancient site that cannot be recognized as a geographical area.

From the viewpoint of cultural relics protection level, the 249 cultural relics include 9 national key cultural relics protection units, 15 provincial cultural relics protection units, 29 municipal and county cultural relics protection units, and 195 have not yet been approved as protection units. Among them, there are 8 national key cultural relics protection units for ancient buildings, 1 for modern important historical sites and representative buildings, 12 provincial cultural relics protection units for ancient buildings and 3 modern important historical sites and representative buildings, city and county-level cultural relics protection units cover a wider range, including 11 ancient buildings, 1 ancient tombs, 3 ancient sites, 14 modern important historical sites and representative buildings. From the above data, it can be seen that the high-level immovable cultural relics are mainly ancient buildings and a small number of

important historical sites and representative buildings of modern times, and there are no ancient tombs and sites selected, and nearly 80% of the total 249 immovable cultural relics have not been approved as protection units.

On the whole, most of the 200-odd approved immovable cultural relics have different degrees of damage, and only a small number of them have been protected by development companies or residents and are well preserved. Most of the buildings are beyond repair due to the impact of natural or social factors such as old age, vacancy, etc. There are common problems such as serious water leakage, decaying wooden structures, infestation by termites, and plant growth that breaks through the building structure. Some of the buildings, such as the residential house at No. 6 Jinjiajing Lane, were funded by the development company to carry out comprehensive repairs to the building, so that the building has been well maintained. Some of the buildings have been partially demolished as a result of secondary development, and the overall structure has been altered.

3.2. Visualization Output

According to the content of immovable cultural relics in Jiangbei District, the database is designed as follows: there are six first-level columns (home page, cultural relics can be viewed, publicity reports, intelligent question and answer system, regulatory documents, relevant links), and the second-level columns or third-level columns are set up under the first-level columns according to different needs. See **Table 1** for details.

3.3. Case Application (Optional)

With the support of the GraphRAG process, this study successfully automatically identified and extracted over 3,500 entity nodes and more than 5,200 semantic relationships from traditional textual descriptions of cultural relics. Consequently, a preliminary knowledge graph of cultural heritage in Jiangbei District was constructed.

The extracted entity types primarily include “cultural relic name”, “location”, “era”, “use”, “architectural structure”, and “building structure”. The relationship types encompass “located in”, “built in”, “belonged to”, “destroyed in”, among 12 distinct semantic associations. Such a comprehensive representation enables a nuanced understanding of the spatial, temporal, and functional characteristics of cultural heritage data.

Table 1. The framework structure of the network database of immovable cultural relics in Jiangbei District.

Level 1 columns	Content	Presentation
Home	Database name and description, column name, search function box, homepage banner, copyright information	Text, pictures
Artifacts can be viewed	The time, space and entity relationship of immovable cultural relics in Jiangbei District can be viewed	Entity Relationship Graph Module
Propaganda coverage	News reports on the team’s field research process and related reports on the protection process of immovable cultural relics	According to the theme of the report, there are two secondary columns: team report and cultural relics protection process
Intelligent question answering system	Based on the theme of immovable cultural relics in Jiangbei District, visitors can enter questions in the dialog box, and the model will give answers	The search box and the IP image designed by the team are used as Q&A bots
Regulatory documents	Letters and replies from governments and management departments at all levels on the management, protection, planning, monitoring, and development of immovable cultural relics	It is mainly based on government documents and approvals, including the name of the document, unit, time, etc.
Related Links	Research websites and videos related to the protection of immovable cultural relics and cultural heritage in Jiangbei District.	There are two secondary columns of website links and video links, which can be viewed directly

The system's extraction accuracy was evaluated against a manually calibrated sample, achieving a precision rate exceeding 92%. This high level of accuracy indicates that the system demonstrates reliable usability in identifying and linking cultural heritage entities and relationships, effectively supporting data integration and knowledge representation.

Furthermore, the preliminary deployment of a Q&A interface demonstrates the system's capability to handle natural language queries. Examples include "What are the Qing Dynasty brick and wood structure cultural relics in Jiangbei District?" and "Which cultural relics are associated with Yangtze River culture?". This module provides a feasible pathway for the future construction of an intelligent cultural heritage knowledge service system, offering new possibilities for integrating AI with cultural heritage research.

4. Discussion

4.1. Value Analysis of Data Structuring and Spatial Representation

The study's findings highlight the effectiveness of a multifaceted approach that integrates data cleansing, standardization, and structural reorganization. This methodological framework significantly enhances the systematicity and consistency of cultural heritage census data in Jiangbei District, laying a solid foundation for scientific management, spatial analysis, and historical evolution research. By supplementing and accurately positioning geographic information, the study has transformed immovable cultural relics into visible, searchable, and analyzable data, thereby providing substantial support for local cultural heritage protection.

The results reveal that the cultural relics are predominantly distributed along the banks of the Yao River and its tributaries, with the ancient county town of Cicheng serving as the core concentration area. Most relic sites are situated in historically dense settlements, particularly in Cicheng, Yongjiang, and Kongpu streets. This spatial pattern aligns with the urban development history of Jiangbei District, reflecting the region's characteristic principle of "built by water and developed by harbor". Such findings underscore the intrinsic connection between local culture and geographical environment.

The integration of Geographic Information System (GIS) for delineating cultural resources not only facilitates exhibition and visualization but also provides valuable references for urban planning and the design of cultural tourism pathways. This dual function of data representation and practical application exemplifies the potential of GIS technology in promoting cultural heritage preservation and sustainable urban development.

4.2. Knowledge Dissemination and Service Significance of The Visualization Platform

The visualization platform developed in this study incorporates maps, charts, and timelines, thereby providing users with convenient and efficient access to information. The system has been demonstrated to be especially effective in terms of facilitating communication in three distinct areas: cultural heritage, science education, and the involvement of non-specialized users. By expanding the communication channels that are difficult to reach through traditional archives or written materials, the system has proven to be a valuable resource.

The platform is designed to facilitate interactive exploration, offering intuitive information, straightforward operation, and rapid response. Its versatility extends to various scenarios, including mobile promotion, multimedia presentations in exhibition halls, and community cultural promotion. The platform's integration of these capabilities is anticipated to enhance public awareness and recognition of cultural heritage.

4.3. Technical Value and Innovative Significance of Introducing GraphRAG

The application of GraphRAG in the semantic modeling of cultural heritage data represents an inaugural exploration in the domain of local cultural heritage research. The proposed method has the capacity to automatically extract key semantic knowledge from unstructured text. In addition, it can further construct a knowledge graph with queryable and reasonable capabilities. Consequently, it significantly improves the knowledge density and intelligent processing level of cultural heritage data. The system's

primary benefit lies in its ability to transition from conventional data storage to the transformation of knowledge services, while concurrently facilitating natural language interaction. This enhancement is designed to address the multifaceted and customized information access requirements of both the public and managerial personnel. Furthermore, the integration of this method with Geographic Information Systems (GIS) offers a viable approach to developing a semantics-driven spatial exploration interface. This technical approach establishes a substantial technical foundation for the subsequent development of local cultural digital archives, intelligent guiding systems, and semantic recommendation engines. Furthermore, it serves to broaden the research boundaries and the practice space of cultural heritage digitization.

4.4. Limitations and Future Research Directions

Despite the study's notable achievements in the domains of cultural heritage data integration and intelligent construction, certain shortcomings persist. Firstly, the integrity of the data is still questionable, as certain cultural relics are missing image data, structural drawings, and material information. This limitation restricts the subsequent in-depth analysis and multi-dimensional modeling. Secondly, the GraphRAG model's capacity to discern the contexts of ancient terms and local dialects during the semantic extraction process remains inadequate, leading to a degree of semantic misjudgment and structural incompleteness of the knowledge graph. Moreover, the present system's functionality is predominantly oriented towards basic information display, exhibiting a lack of sophistication in user-oriented extension modules such as intelligent recommendation, route planning, and thematic narrative. The platform's failure to implement a user-generated content (UGC) mechanism has resulted in a relatively low level of public participation, hindering the platform's capacity to effectively stimulate the enthusiasm of community residents in the domains of cultural relics recording and cultural dissemination.

Future research in this field can be expanded in several dimensions. First, the incorporation of heterogeneous data from multiple sources, including aerial images, 3D models, and historical maps, among others, is recommended. In order to enhance the breadth and depth of the database, it is necessary to further optimize the natural language processing model. This will improve the adaptability and extraction accuracy of GraphRAG in dealing with local languages and cultural contexts. In order to strengthen the interconnectivity and interoperability between the platform and the governmental affairs system and cultural management system, it is necessary to promote the application of research results in urban governance and cultural preservation practices. In order to construct an interactive mechanism centered on "community building and sharing," it is necessary to encourage residents to participate in the digital construction of local culture. Third, efforts must be made to strengthen the interconnection between the platform, governmental affairs system, and cultural management system. Furthermore, the application of research results in urban governance and cultural protection practice must be promoted. Fourth, an interactive mechanism centered on "community co-construction and sharing" must be built. Residents must be encouraged to participate in the digital construction and memory co-creation of local cultures. This will allow for the realization of the paradigm shift of cultural heritage protection from expert orientation to social synergy.

5. Conclusions

Based on the data of the fourth national cultural relics census in Jiangbei District, Ningbo City, this study constructs a regional cultural heritage database and integrates data visualization and semantic knowledge extraction technology to explore a digital path of local cultural heritage that integrates data integration, intelligent construction, and interactive display. The research results not only improve the information management level of regional cultural heritage but also provide technical support and methodological demonstration for the protection, dissemination, and reuse of cultural resources. The conclusions and findings are mainly reflected in the following aspects:

5.1. Standardization and Structured Improvement of Data Management

The study utilizes a systematic approach to manage cultural relics information by cleaning, coding, and spa-

tial positioning the original data. This methodical process addresses the challenges posed by irregularities and inconsistencies present in the initial data, thereby ensuring the integrity and reliability of the cultural relics information. The number of cultural relics, category structure, age distribution, and preservation status can be accurately presented, providing a reliable basis for the government to carry out scientific supervision and accurate protection.

5.2. Constructing A Database System with Sustainable Updating and Multi-dimensional Query Capability

The research has developed a cultural heritage database platform that supports multidimensional search, visualization linkage, and continuous updating. This enhancement of the transformation of cultural resources from "static archives" to "dynamic services" is a significant contribution of this study. The system boasts commendable portability and extensibility, thus providing a technical template for local governments in the realm of cultural digital governance.

5.3. Visualization Technology Expands the Boundaries of Cultural Communication

The interactive display system based on the map engine and graphical tools realizes the comprehensive visual expression of the spatial distribution, historical evolution and attribute characteristics of cultural relics, which lowers the threshold of understanding cultural data, enhances the public accessibility and communication efficiency of cultural heritage, and further promotes the sense of social and cultural identity as well as the awareness of heritage protection.

5.4. Introducing GraphRAG to Realize Semantic Breakthrough in Knowledge Graph Construction

This study applies GraphRAG technology to the knowledge extraction and semantic modeling of cultural heritage texts, and initially constructs a local cultural knowledge map with semantic reasoning ability, which provides a knowledge foundation for the subsequent development of intelligent Q&A system, semantic search platform and personalized tour application, and promotes the cultural heritage from "visible" to "understandable". It promotes the paradigm shift of cultural heritage from "visible" to "understandable".

5.5. Promote the Development of "Artificial Intelligence + Local Literature and History" Cross-study Research

This study provides empirical cases of the application of artificial intelligence technology in cultural heritage, verifies the effectiveness of graph neural network, knowledge extraction, and map construction methods in cultural and blogging scenarios, and expands the theoretical horizons and technological boundaries of cultural heritage digitization research.

5.6. Serving Multiple Subjects with Potential for Promotion and Extension

The database system not only serves the dynamic supervision of cultural administrative departments, but also can be applied to scientific research institutions, educational units, and public cultural platforms, with good openness and a life cycle management mechanism. In the future, it can be further expanded into "Jiangbei Digital Cultural Map" and even regional "City Cultural Gene Platform", realizing the extensive sharing and value extension of cultural heritage information.

To summarize, the construction of the cultural heritage database in Jiangbei District is not only a digital integration project of local cultural resources, but also a cultural cognition project, a memory protection project, and a public service project with far-reaching impact. This study preliminarily verifies the possibility of constructing an AI-driven cultural heritage knowledge system and provides a replicable and scalable practice sample for the systematic and intelligent protection and dissemination of China's regional cultural heritage.

Future work can further deepen the quality of automatic construction of knowledge maps, improve the interactive function of the system, and expand the public participation mechanism, which will ultimately promote the "revitalized use and universal sharing" of cultural heritage

resources in the digital era.

Author Contributions

Conceptualization, M.F.X. and W.C.J.; methodology, M.F.X.; validation, M.F.X. and W.C.J.; investigation, M.F.X.; writing—original draft preparation, M.F.X.; writing—review and editing, M.F.X.; supervision, W.C.J.; project administration, W.C.J.; All authors have read and agreed to the published version of the manuscript.

Funding

This work received no external funding.

Institutional Review Board Statement

This study neither involves human subjects nor animal subjects. Thus, ethical review related to human or animal research is not applicable.

Data Availability Statement

No new data were created in this study.

Acknowledgments

This article is supported by the Digital Culture Innovation Center of Ningbo Tech University. Thanks for the data and site support.

Conflicts of Interest

The authors declare no conflict of interest.

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