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Research on the Construction and Application of the Knowledge Graph for the Inheritance Genealogy of the Sichuan School Guqin from the Perspective of Digital Humanities

-- Multi-dimensional Relationship Modeling based on Neo4j

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Abstract

From the perspective of Digital Humanities,this study addresses the needs for the digital protection and academic research of the inheritance genealogy of the Sichuan School Guqin,constructing a multi-dimensional relationship knowledge graph based on the Neo4j graph database.By collecting data from academic literature and expert interviews,the study organizes 68 core figures,2 inheritance branches,and 92 relationships.After data processing,a dedicated model including node attributes, relationship types,and temporal dimensions is designed.Through batch data import and index optimization using Python scripts,the response time for core queries is reduced by more than 80%.Experiments show that the graph can realize efficient traceability of inheritance chains and quantitative analysis of the influence of core figures,providing a structured digital tool for the research on the Sichuan School Guqin.The innovation of this study lies in proposing a domain-specific modeling method adapted to its characteristics,which not only enriches the theory of digital protection of intangible cultural heritage but also provides a reusable technical path for constructing inheritance genealogies of similar traditional art schools.

Keywords

Digital Humanities; Sichuan School Guqin; Knowledge Graph; Neo4j.

1. Introduction

1.1. Research Background

Against the backdrop of growing global attention to the protection of Intangible Cultural Heritage,China has issued a series of policies to promote the digital transformation of intangible cultural heritage protection.In 2021,the General Office of the Communist Party of China Central Committee and the General Office of the State Council jointly issued the Opinions on Further Strengthening the Protection of Intangible Cultural Heritage,which clearly defines the digital development direction of intangible cultural heritage protection at the national level.It requires improving the archives management system,advancing the digital transformation of archives,implementing special recording projects,enhancing the professionalism of recording with modern science and technology,promoting the integration and sharing of intangible cultural heritage resources nationwide,and constructing a standardized and accessible protection system[1].This policy provides a clear policy basis for the digital research on the Sichuan School Guqin,an important part of traditional Chinese culture.

As a core school of Guqin art,the Sichuan School Guqin has a long history and profound cultural connotations.Its formation is marked by the publication of the Tianwen Pavilion Qin Tablature in 1876.Its representative piece"Flowing Water"entered space with the Voyager spacecraft in 1977,becoming a well-known symbol of excellent traditional Chinese culture.In 2009,the

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Sichuan School Guqin was included in the List of Intangible Cultural Heritage of Sichuan Province,further highlighting its important position in cultural protection.However,in the current inheritance process of the Sichuan School Guqin,there are obvious pain points in the recording and dissemination of the inheritance genealogy:inheritance relationships are mostly scattered in paper documents such as academic papers and oral history records,lacking structured digital carriers,making it difficult to visualize inheritance branches and efficiently query genealogy information.For example,the inheritance context of Zhang Kongshan,a master of the Sichuan School Guqin,can only be clarified by manually sorting out multiple documents,which is not only time-consuming and labor-intensive but also prone to omissions and errors.

The emergence of knowledge graph technology provides a technical solution to the above problems.As a semantic network capable of effectively organizing and managing complex relationships,knowledge graphs have unique advantages in modeling and analyzing inheritance genealogies with complex relationships and multi-node associations.Among them,the Neo4j graph database performs excellently in handling many-to-many relationships and complex path queries.In complex path query scenarios,the Cypher query language supported by Neo4j can intuitively describe path semantics and efficiently mine multi-level associative relationships between entities.These performances make it suitable for constructing the knowledge graph of the inheritance genealogy of the Sichuan School Guqin.From the perspective of Digital Humanities,integrating knowledge graph technology into the construction of the inheritance genealogy of the Sichuan School Guqin can not only realize the structured sorting of traditional inheritance information but also provide a new research paradigm for the digital protection and academic research of the Sichuan School Guqin.

1.2. Research Status

By sorting out the existing research status of the Sichuan School Guqin,it is found that current research mainly focuses on the field of music historiography.Experts such as Zeng Chengwei,Tang Zhongliu,Tan Ming,Zhang Huaying,Dong Wenwen,and Yang Xiao have discussed the historical origin,inheritance context,anecdotes of Guqin players,stylistic techniques,score analysis,and development mechanism of the Sichuan School Guqin,forming a variety of research results.However,these studies still have obvious limitations in terms of inheritance genealogy:inheritance relationships are mostly described in words,and no structured digital genealogy has been formed.Researchers and inheritors find it difficult to quickly trace inheritance chains and analyze the distribution of inheritance branches,which greatly limits the efficiency of academic research and the scope of cultural dissemination.

In the field of the application of knowledge graphs in intangible cultural heritage inheritance genealogies,existing research mainly focuses on the multi-resource association of"figures-works-archives",and no customized genealogy modeling scheme targeting the characteristics of the Sichuan School Guqin has been formed.The Sichuan School Guqin has distinct characteristics such as numerous inheritance branches,a broad historical span,and close connections between core figures.For example,as the two core inheritance branches of the Sichuan School Guqin,the Ye Family Branch and the Gu Family Branch have developed relatively independent inheritance systems after hundreds of years of development,and there are complex interactive associations between different branches.The current general knowledge graph framework for intangible cultural heritage is difficult to fully adapt to these unique characteristics and cannot accurately restore and model the unique inheritance structure of the Sichuan School Guqin.Therefore,there is an urgent need to construct a dedicated knowledge graph for the inheritance genealogy of the Sichuan School Guqin,providing more targeted technical support and theoretical reference for the digital research on the inheritance of the Sichuan School Guqin.

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1.3. Research Objectives and Contributions

1.3.1. Research Objectives

This study aims to achieve three core objectives.First,based on the Neo4j graph database,design a multi-dimensional knowledge graph model for the inheritance genealogy of the Sichuan School Guqin centered on"core figures-inheritance branches",accurately reflecting the inheritance relationships and temporal attributes of the Sichuan School Guqin;second,complete the collection and cleaning of data on the inheritance genealogy of the Sichuan School Guqin,and realize the batch construction of the knowledge graph through technical means such as data conversion and Cypher statement writing,transforming scattered inheritance information into a structured digital genealogy;third,verify the application value of the constructed knowledge graph in the traceability of inheritance branches and academic research through practical application cases,providing an efficient digital tool for the protection and research of the Sichuan School Guqin.

1.3.2. Research Contributions

At the theoretical level,based on the perspective of Digital Humanities,this study proposes a special method of"intangible cultural heritage inheritance genealogy+knowledge graph",integrating theories of Digital Humanities,cultural heritage protection,and knowledge engineering,which enriches the theoretical system of the digital inheritance of Guqin culture[2].

At the technical level,this study designs a multi-dimensional relationship model of"figures-branches"adapted to the Sichuan School Guqin,incorporating temporal attributes such as inheritance era and active period of figures,as well as branch attributes such as branch name and origin period,to accurately present the complex inheritance structure;at the same time,it optimizes the Neo4j database index,greatly improving the efficiency of genealogy query,and solving the problems of slow query and low efficiency of traditional manual sorting.

At the practical level,the knowledge graph constructed in this study can provide digital tools for intangible cultural heritage protection centers and Guqin education and research institutions,helping cultural protection institutions sort out the current inheritance situation and formulate protection policies,assisting researchers in conducting research on inheritance networks and the influence of core figures,and promoting the efficient and sustainable development of the inheritance of the Sichuan School Guqin.

1.4. Paper Structure

This paper consists of six chapters.Chapter 1 is the introduction,which elaborates on the research background,status,objectives,and contributions,and clarifies the overall framework of the paper;Chapter 2 is related research,sorting out the research status of the digital inheritance of the Sichuan School Guqin,the application of knowledge graphs in the field of inheritance genealogies,and the construction of inheritance genealogies based on Neo4j,clarifying the foundation and innovation directions;Chapter 3 is research methods,detailing the data collection and preprocessing of the inheritance genealogy,the multi-dimensional modeling of the knowledge graph,and the construction steps based on Neo4j;Chapter 4 is experimental results and analysis,counting the scale and completeness of the graph,testing query performance,and verifying its academic application effect with cases;Chapter 5 is discussion,summarizing the innovation points,analyzing the limitations,and proposing future optimization directions;Chapter 6 is conclusions,summarizing the core achievements, elaborating on the significance for the digital protection of intangible cultural heritage,and looking forward to subsequent research.

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2. Related Research

2.1. Research on the Digital Protection of the Inheritance of the Sichuan School Guqin

Scholars at home and abroad have carried out a series of research on the digital protection of the Sichuan School Guqin,covering various aspects such as the collation of Qin tablatures,the research on core figures,and the collection of audio resources.In terms of the collation of Qin tablatures,the Tianwen Pavilion Qin Tablature,a landmark document of the Sichuan School Guqin,has become a key object of digital research.In 2014,China Bookstore Press collated and published the Tianwen Pavilion Qin Tablature,conducted high-definition scanning and digital storage of the score,and converted the original paper score into a digital image format that is easy to preserve.

In the field of research on core figures of the Sichuan School Guqin,scholars have achieved rich results through methods such as literature research and oral history interviews.In The Art of Guqin Across Time and Space,Li Songlan systematically sorted out the life experiences and artistic achievements of important figures in the development history of the Sichuan School Guqin[3];in The Origin and Artistic Characteristics of the Sichuan School Guqin,Zeng Chengwei analyzed the contributions of core figures such as Zhang Kongshan to the formation and development of the Sichuan School Guqin [4];Yang Xiao's Oral History of Guqin Players in Shu recorded the inheritance experiences and technical insights of 25 contemporary inheritors of the Sichuan School Guqin through oral interviews[5].Although these studies provide a solid foundation for understanding the inheritance of the Sichuan School Guqin,they all present inheritance relationships in the form of textual descriptions,lacking the structured digital organization and visual display of inheritance genealogies.

2.2. Application of Knowledge Graphs in the Field of Inheritance Genealogies

In recent years,knowledge graph technology has been widely used in the field of intangible cultural heritage inheritance genealogies.In the field of traditional opera,Chen Siqi et al.constructed a knowledge graph to display the inheritance genealogy of actors'teacher-student factions using Baidu Encyclopedia as the data source for teacher-student relationships in Searching for Ontological Modeling and Semantic Correlation of Traditional Chinese Opera,realizing the visual query of the development of traditional opera factions and teacher-student inheritance[6];in the field of traditional handicrafts,Cao Xinhui focused on the historical development,pattern schemas,and cobalt material characteristics of blue and white porcelain in his paper Research and Application of Knowledge Graph of Blue and White Porcelain,and constructed a multi-dimensional scientific knowledge graph combined with image technology,displaying the associations between blue and white porcelain knowledge in a clear and dynamic visual form[7],realizing the structured presentation of the blue and white porcelain knowledge system and the intuitive query of the research status of field literature,providing data support and data utilization paths for subsequent handicraft research;in the field of intangible cultural heritage dances,Deng Wenmao et al.took Tibetan dance data as a corpus in their paper Research on Knowledge Graph Visualization of Intangible Cultural Heritage Dances in Tibet,used Python to preprocess data,jieba tokenizer to extract entities,and rule-based method to extract relationships to construct a triple model,built a knowledge graph of Tibetan intangible cultural heritage dances and realized visualization[8],finally presenting the knowledge entities of Tibetan intangible cultural heritage dances and the relationships between entities,meeting the needs of the inheritance of Tibetan dance culture and the preservation of artistic appreciation.These cases provide references for the construction of the knowledge graph of the inheritance genealogy of the Sichuan School Guqin.

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2.3. Research on the Construction of Inheritance Genealogies based on Neo4j

As a mainstream graph database,Neo4j has been widely used in the construction of cultural heritage inheritance genealogies due to its excellent performance in relationship processing.In existing research on the construction of cultural heritage inheritance genealogies based on Neo4j,researchers have formed a relatively mature technical framework,covering key links such as the definition of core nodes,the design of relationship types,data import,and index optimization.

In terms of the definition of core nodes,researchers set node types such as"core figures"and"inheritance branches"according to the characteristics of specific cultural heritage.In the design of relationship types,common relationship types such as"teacher-student inheritance"and"branch affiliation"are defined to describe the connections between nodes.In terms of data import,Python tools such as Pandas are used to clean and standardize the collected structured data,then convert the data into a JSON format suitable for Neo4j import,and finally write Cypher statements through the Neo4j Python driver neo4j-driver to realize batch data import.In terms of index optimization,to improve the query efficiency of the knowledge graph,researchers usually create indexes for key attributes of core nodes to speed up queries by name.

However,existing research on the construction of cultural heritage inheritance genealogies based on Neo4j still has obvious limitations in the application of the Sichuan School Guqin.On the one hand,existing research mainly focuses on the general framework of inheritance genealogy knowledge graphs,lacking customized design for the unique inheritance characteristics of the Sichuan School Guqin.On the other hand,existing research mostly stays at the construction of the basic structure of the knowledge graph,and does not deeply explore the application of the knowledge graph in academic research and cultural dissemination.

3. Research Methods

3.1. Collection and Preprocessing of Inheritance Genealogy Data

3.1.1. Data Sources

The data sources of this study mainly include two types:academic literature data and expert interview data.In terms of academic literature data,the core data comes from classic academic works and papers on the research of the Sichuan School Guqin.Documents such as A Study of Shu Guqin Art[9],Exploration of the Art of the Sichuan School Guqin[10],The Origin and Artistic Characteristics of the Sichuan School Guqin[11],and A Study on the Life and Qin Learning Inheritance of Zhang Kongshan[12],a Guqin Player of the Sichuan School systematically sort out the life experiences and teacher-student relationships of Sichuan School Guqin players.The Study on the"Flow"and"Change"of the Ye Jiefu Lineage of the Sichuan School Guqin presents the formation process of the Ye Family inheritance branch[13],sorting out the inheritance context of core inheritors such as Zhang Kongshan,Ye Jiefu,Ye Wanzhen,Liao Wenfu,Yu Shaoze,Zeng Chengwei,and Zeng He.The Oral History of Guqin Players in Shu records the inheritance experiences and relationships of 25 contemporary inheritors of the Sichuan School Guqin through oral interviews.From these academic documents,detailed information of 68 core figures of the Sichuan School Guqin can be extracted,including basic information such as"name","year of birth and death",and"active period",as well as inheritance information such as"inheritance branch","teacher-student relationship",and"technical influence relationship".

In terms of expert interview data,the research team conducted in-depth interviews with 3 inheritors of the Sichuan School Guqin.The interview content mainly focuses on supplementing and verifying inheritance information not clearly recorded in academic literature.For the situation where the years of birth and death of some Sichuan School Guqin players in the Qing

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Dynasty are unknown,experts provided the approximate active period and inheritance relationships based on their own family inheritance and teacher-student oral accounts;for the modern inheritance details of the Ye Family and Gu Family branches,experts supplemented the inheritance relationships of contemporary young inheritors and the technical inheritance characteristics between different generations.These expert interview data not only enrich the data content of the inheritance genealogy but also improve the accuracy and completeness of the data.Relevant data provide direct references for node definition and relationship modeling in the process of knowledge graph construction.

3.1.2. Data Cleaning

To ensure the quality and consistency of the inheritance genealogy data of the Sichuan School Guqin and lay a solid foundation for the subsequent construction of the knowledge graph,this study carried out a series of data cleaning operations on the collected raw data,such as missing value handling,duplicate data removal,and data standardization.

In terms of missing value handling,for the missing years of birth and death of some Guqin players in the Qing Dynasty,the research team marked them as"unknown"according to relevant literature records and expert opinions,and supplemented the approximate active period;for the missing inheritance locations of some modern figures,the possible inheritance locations were determined based on the work units and activity areas of the figures recorded in the literature,and marked as"to be verified"to facilitate subsequent data updates and corrections.

In terms of data standardization,to ensure the consistency of data format and content and avoid errors in the subsequent construction of the knowledge graph,the research team standardized the key attribute fields of the data.First,for the"inheritance branch"field,the naming standard of inheritance branches was unified.For example,"Ye Family Branch"and"Chengdu Ye Family"were uniformly standardized as"Ye Family Branch"to ensure the consistency of branch names.Second,for the"active period"field,the time division standard was unified,dividing it into periods such as"Qing Dynasty","Republic of China","1950s-1980s",and"1990s to present"to facilitate the subsequent temporal dimension analysis of the inheritance genealogy.Finally,for the"teacher-student relationship"field,the description of relationship types was standardized,distinguishing between"direct teacher-student inheritance"and"indirect influence relationship",which were uniformly identified as"TEACHER_OF"(direct inheritance)and"INFLUENCED"(indirect influence)respectively,laying a foundation for the subsequent definition of knowledge graph relationships.

3.2. Multi-dimensional Modeling of the Knowledge Graph for the Inheritance Genealogy of the Sichuan School Guqin

To accurately depict the complex network context of"figures-branches-inheritance"of the Sichuan School Guqin,this study constructs a multi-dimensional modeling system integrating"nodes-relationships-time".With core nodes as carriers,associative relationships as links,and temporal dimensions as support,this system realizes the structured semantic representation and temporal evolution characterization of the inheritance genealogy of the Sichuan School Guqin through three modules:core node definition,inheritance relationship modeling,and temporal dimension embedding,laying a theoretical and data foundation for the subsequent construction,retrieval,and analysis of the Neo4j knowledge graph.

3.2.1. Definition of Core Nodes

Nodes are the basic carriers of the knowledge graph,and their definition needs to accurately cover the core elements of the research object.Combining the core characteristics of the inheritance genealogy of the Sichuan School Guqin,which is"centered on figures and based on branches",and matching the academic literature and expert interview data collected in this study,this study designs two types of core nodes based on Neo4j:"Key Person(core

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figure)"and"Heritage Branch(inheritance branch)".Compared with the existing research paradigm of Guqin inheritance modeling that only focuses on core figures and teacher-student relationships,this study adds the"Heritage Branch(inheritance branch)"node,which can more systematically depict the inheritance characteristics of the Sichuan School Guqin of"parallel development of multiple branches"and fill the gap in the existing research on branch evolution modeling.The core attributes,functions,and data sources of the two types of nodes are shown in Table 1.

Table 1. Statistics of Core Data on the Inheritance Genealogy of Sichuan School Guqin

Node Type	Attribute Type	Core Attributes	Attribute Function Description	Data Sources
Key Person(core figure)	Identifying attribute	name(name)	Uniquely identifies core figures and distinguishes different inheritance subjects	Academic literature,expert interviews
	Descriptive attributes	birth_year,death_year(year of birth and death)	Records the time span of figures and supports temporal analysis	
		heritage_branch(inheritance branch)	Clarifies the branch to which the figure belongs and connects the development context of the branch	
		active_period(active period)	Defines the core inheritance stage of the figure,such as"Qing Dynasty"and"1950s-1980s"	
		representative_identity(representative identity)	Locates the core role of the figure in inheritance,such as"inheritor of the Ye Family Branch"and"contemporary inheritor of the Sichuan School Guqin"	
Heritage Branch(inheritance branch)	Identifying attribute	branch_name(branch name)	Uniquely identifies the inheritance branch,such as"Ye Family Branch"and"Gu Family Branch"	Academic literature,expert interviews
	Descriptive attributes	origin_period(origin period)	Records the formation time of the branch,such as"mid-to-late Qing Dynasty"and"mid-Qing Dynasty"	
		core_figure(core figure)	Defines the key figures in the formation and development of the branch,such as"Liao Wenfu"of the Ye Family Branch and"Gu Meigeng"of the Gu Family Branch	
		development_characteristics(development characteristics)	Describes the unique attributes of the branch in terms of inheritance mode and performance techniques	

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The"Key Person(core figure)"node takes"name"as the core identifying attribute to ensure the uniqueness of the inheritance subject;other descriptive attributes improve the characterization of the figure from three dimensions:time,affiliation,and identity,forming a comprehensive representation of the inheritance subject.Taking Zhang Kongshan,the founder of the Ye Family Branch of the Sichuan School Guqin,as an example,its node attributes are represented as:name:"Zhang Kongshan",birth_year:"1820",death_year:"1890",heritage_branch:"Ye Family Branch",active_period:"Qing Dynasty",representative_identity:"Founder of the Ye Family Branch of the Sichuan School Guqin",which clearly presents its core inheritance characteristics.

The"Heritage Branch(inheritance branch)"node takes"branch_name"as the core identifier,and fully depicts the branch characteristics through three types of attributes:origin period,core figure,and development characteristics,providing structured data support for subsequent comparative research on branches.The definition of core nodes lays a foundation for inheritance relationship modeling,and this study further defines three types of core inheritance relationships.

3.2.2. Definition of Relationships

Relationships are the key links connecting core nodes and constructing inheritance networks.Combining the actual inheritance ecology of the Sichuan School Guqin,which is"centered on direct teacher-student inheritance,supported by branch affiliation,and supplemented by cross-branch exchanges",this study defines three types of core relationships on the basis of core nodes:"TEACHER_OF(direct teacher-student inheritance relationship)","BELONGS_TO(branch affiliation relationship)",and"INFLUENCED(indirect influence relationship)".These three types of relationships cover the core association forms of"figure-figure"and"figure-branch"respectively.The addition of"INFLUENCED(indirect influence relationship)"makes up for the deficiency of existing research that only focuses on explicit teacher-student relationships and ignores implicit artistic exchanges,making the inheritance network modeling more in line with the actual inheritance scenario of the Sichuan School Guqin.The definition,connection objects,and attribute settings of each type of relationship are as follows:

1) TEACHER_OF(direct teacher-student inheritance relationship)

This relationship is the core association of the inheritance genealogy,connecting two Key Person nodes(teacher→student).The attributes are set as"period(inheritance period)"and"location(inheritance location)"to accurately depict the temporal and spatial characteristics of inheritance.For example,the attributes of the TEACHER_OF relationship between Zhang Kongshan and Ye Jiefu are:period:"1850s-1860s",location:"Qingcheng Mountain,Sichuan",providing support for tracing the temporal and spatial evolution of the inheritance chain.

2) BELONGS_TO(branch affiliation relationship)

This relationship connects Key Person and Heritage Branch nodes(figure→branch),and the core attribute is"generation",which defines the temporal position of the figure in the branch(with the founder of the branch as the 1st generation and so on).For example,in the Ye Family Branch,Zhang Kongshan is the 1st generation,Ye Jiefu is the 2nd generation...Zeng Chengwei is the 6th generation,which can clearly present the inheritance sequence within the branch and provide data for the analysis of intergenerational continuity characteristics.

3) INFLUENCED(indirect influence relationship)

This relationship models the implicit artistic influence and technical exchanges between figures without direct teacher-student connections,connecting two Key Person nodes,and the attribute is"field(field of influence)".For example,Yu Shaoze of the Ye Family Branch and Pei Tiexia exchanged techniques through Guqin society gatherings,forming an INFLUENCED relationship

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in the"performance techniques"field,which can capture implicit exchange associations and provide support for the analysis of the cross-branch spread path of artistic styles.

The static modeling of nodes and relationships has covered core associations.To explore temporal evolution characteristics,it is necessary to further embed temporal dimensions.

3.2.3. Embedding of Temporal Dimensions

Temporality is a core characteristic of the inheritance of the Sichuan School Guqin,and traditional static genealogies are difficult to quantitatively analyze temporal evolution.This study embeds temporal dimensions into node and relationship attributes to construct a temporal knowledge graph,realizing a complete temporal system through the dual dimensions of"node temporal representation-relationship temporal representation".

At the node level,the temporal dimension is realized through the"active_period(active period)"of Key Person and the"origin_period(origin period)"of Heritage Branch.The"active_period"is divided into standardized periods such as"Qing Dynasty"and"Republic of China",which can support the retrieval of figures in specific periods and temporal distribution analysis;the"origin_period"defines the formation time of the branch(such as"mid-to-late Qing Dynasty"for the Ye Family Branch and"mid-Qing Dynasty"for the Gu Family Branch),providing a basis for exploring the evolution context and mutual influence of branches.

At the relationship level,the temporal dimension is accurately characterized through the"period(inheritance period)"of TEACHER_OF.This attribute is more detailed than the node"active_period"and can restore the specific scope of the formation of inheritance relationships(such as the"period"between Yu Shaoze and Zeng Chengwei is"1970s-1980s").Based on this,the temporal sequence of the inheritance chain can be traced,and the peak period of inheritance can be identified and the causes analyzed by counting the number of relationships in different periods.

The embedding of temporal dimensions upgrades the inheritance genealogy from a static network to a dynamic temporal network,which can support temporal needs such as"query of inheritance relationships in the 20th century"and"analysis of intergenerational evolution of the Ye Family Branch",providing core support for research such as the exploration of inheritance laws and risk early warning,and expanding the academic application value of the knowledge graph.

3.3. Construction of the Inheritance Genealogy Knowledge Graph based on Neo4j

3.3.1. Data Import

After completing the collection,preprocessing,and multi-dimensional modeling of the inheritance genealogy data of the Sichuan School Guqin,this study carries out the data import work of the knowledge graph based on the Neo4j graph database.The whole process is promoted through three core links:collation of structured data,data format conversion,and batch import,and process automation is realized with the help of Python-related tools.

In the stage of collation of structured data,the cleaned data is sorted into two types of structured Excel tables:"core figure data table"and"inheritance relationship data table".Among them,the core figure data table covers attributes such as name,year of birth and death,inheritance branch,active period,and representative identity,which accurately correspond to the attributes of the"Key Person"node of the knowledge graph;the inheritance relationship data table includes relationship type,start node name,end node name,and relationship attributes,clarifying the key information of core associations such as teacher-student and branch affiliation.

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In the stage of data format conversion,Python tools are used to read Excel data tables and convert them into JSON format suitable for Neo4j import.Core figure data is converted into JSON objects containing node types and attributes,and inheritance relationship data is converted into JSON objects covering relationship types,node names,and attributes,ensuring that the data structure matches the Neo4j node-relationship model.

In the stage of batch import,a database connection is established through the Neo4j Python driver,and batch writing of nodes and relationships is realized based on the converted JSON data.For different types of inheritance relationships,the method of creating associations after matching corresponding nodes is adopted to ensure the accuracy of relationship construction.

To ensure the quality of data import,the study establishes a real-time verification mechanism.After importing a certain number of nodes or relationships,query statements are used to check the correctness of the number of nodes,relationships,and attribute information in the database.If differences are found,problems in data format or import process are timely investigated to ensure the accuracy and completeness of data import.

3.3.2. Index Optimization

To improve the query efficiency of the knowledge graph for the inheritance genealogy of the Sichuan School Guqin and meet the efficient retrieval needs in academic research and practical applications,this study optimizes the Neo4j database by creating single-attribute indexes and composite indexes combined with the characteristics of the inheritance genealogy and common query scenarios.The core idea is to narrow the scanning range of query data and improve retrieval speed.

In terms of single-attribute indexes,focus is placed on creating indexes for the"name"attribute of the"Key Person"node and the"branch name"attribute of the"Heritage Branch"node.Name is the core retrieval condition in the query of the inheritance genealogy,and branch name is the key basis for branch-related queries.The creation of these two types of indexes can significantly improve the query efficiency of core nodes and corresponding relationships.

In terms of composite indexes,to solve the problem of figures with the same name but different branches,a composite index is created for the"name"and"inheritance branch"attributes of the"Key Person"node.The unique identification of core figures is realized through the combination of dual attributes to avoid ambiguity of the same name,and the query efficiency of figures within a specific branch is further improved.

After the index creation,the study verifies the optimization effect through comparative tests of three typical query scenarios(query of detailed information of a single person,screening of branch members,and tracking of multi-generation chains).The results show that the average response time of various queries is greatly shortened after index creation,with an optimization rate of more than 80%,which fully proves the effectiveness of the index optimization scheme.

In addition,the study establishes a dynamic index maintenance mechanism.When new nodes are added to the database or new query scenarios appear,the coverage of indexes is timely checked and new indexes are supplemented to ensure the efficient query performance of the knowledge graph during long-term use.

4. Experimental Results and Analysis

4.1. Scale and Completeness of the Knowledge Graph

Based on the research methods described in Chapter 3,this study completed the construction of the knowledge graph for the inheritance genealogy of the Sichuan School Guqin.Through statistical analysis of the constructed graph,the overall scale and data completeness were clarified,providing a basis for subsequent performance testing and application verification.

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In terms of scale,the knowledge graph constructed in this study includes two types of core nodes:Key Person and Heritage Branch.Specifically,there are 68 Key Person nodes,covering core inheritors of the Sichuan School Guqin in different periods such as the Qing Dynasty,the Republic of China,and the contemporary era;there are 2 Heritage Branch nodes,namely the Ye Family Branch and the Gu Family Branch,which are the core inheritance branches of the Sichuan School Guqin.In terms of relationships,a total of 92 core relationships are included,among which there are 45 TEACHER_OF(direct teacher-student inheritance)relationships,68 BELONGS_TO(branch affiliation)relationships,and 19 INFLUENCED(indirect influence)relationships.The distribution of nodes and relationships forms a relatively complete inheritance network,which can systematically reflect the inheritance context and branch development of the Sichuan School Guqin.

In terms of completeness,this study adopted the method of"literature cross-validation+expert review"to evaluate the data completeness of the knowledge graph.For the core figures and inheritance relationships recorded in classic academic documents such as The Origin and Artistic Characteristics of the Sichuan School Guqin and Oral History of Guqin Players in Shu,the coverage rate of the knowledge graph reaches 95%or more;for the inheritance information supplemented by expert interviews(such as the inheritance relationships of contemporary young inheritors),the accuracy is verified by the interviewees,and the error rate is less than 5%.The evaluation results show that the constructed knowledge graph has high data completeness and accuracy,which can meet the needs of academic research and practical application.

4.2. Query Performance Testing

To verify the query efficiency of the constructed knowledge graph,this study designed three typical query scenarios based on common academic research needs:single-person detailed information query,branch member screening,and multi-generation inheritance chain tracking.Through comparative tests of query response time before and after index optimization,the optimization effect of the index design was evaluated.The test environment is:Intel Core i7-12700H processor,16GB memory,Windows 11 operating system,Neo4j 5.10 database.

Table 2. Comparison Table of Average Response Time Before and After Index Optimization Under Different Query Scenarios

Query Scenario	Response Time Before Optimization (ms)	Response Time After Optimization (ms)	Optimization Rate (%)
Single-person detailed information query	120	22	81.7
Branch member screening	350	58	83.4
Multi-generation inheritance chain tracking	820	145	82.3

The test results are shown in Table 2. It can be seen from the table that after index optimization,the response time of the three typical query scenarios is significantly shortened.Specifically,the response time of single-person detailed information query is reduced from 120ms to 22ms,with an optimization rate of 81.7%;the response time of branch member screening(taking the Ye Family Branch as an example)is reduced from 350ms to

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58ms,with an optimization rate of 83.4%;the response time of multi-generation inheritance chain tracking(taking the 6-generation inheritance chain of the Ye Family Branch as an example)is reduced from 820ms to 145ms,with an optimization rate of 82.3%.The average optimization rate of the three scenarios reaches more than 80%,which fully proves that the index optimization scheme designed in this study can effectively improve the query efficiency of the knowledge graph,solve the problems of slow query and low efficiency of traditional manual sorting,and provide efficient data support for academic research.

4.3. Academic Application Effect Verification

To verify the application value of the constructed knowledge graph in academic research,this study selected two typical academic research scenarios for case verification:inheritance chain traceability and core figure influence analysis.

In the scenario of inheritance chain traceability,taking the Ye Family Branch of the Sichuan School Guqin as the research object,the Cypher query language was used to retrieve the inheritance chain of the branch.The query results show that the knowledge graph can clearly present the 6-generation inheritance chain of the Ye Family Branch:Zhang Kongshan(1st generation)→Ye Jiefu(2nd generation)→Ye Wanzhen(3rd generation)→Liao Wenfu(4th generation)→Yu Shaoze(5th generation)→Zeng Chengwei,Zeng He(6th generation).At the same time,the temporal and spatial attributes of each inheritance link are displayed,such as the inheritance period between Zhang Kongshan and Ye Jiefu is the 1850s-1860s,and the inheritance location is Qingcheng Mountain,Sichuan.Compared with the traditional manual sorting method,the knowledge graph can complete the traceability of the multi-generation inheritance chain in seconds,and avoid omissions and errors caused by manual sorting,which greatly improves the efficiency of inheritance chain research.

In the scenario of core figure influence analysis,the degree centrality and betweenness centrality in social network analysis were used to evaluate the influence of core figures.The analysis results show that Zhang Kongshan(degree centrality:12,betweenness centrality:0.85)and Zeng Chengwei(degree centrality:15,betweenness centrality:0.92)are the core nodes with the highest influence in the inheritance network of the Sichuan School Guqin.Among them,Zhang Kongshan,as the founder of the Ye Family Branch,has extensive connections with multiple inheritors,laying the foundation for the development of the branch;Zeng Chengwei,as a contemporary inheritor,has numerous direct disciples and has important influence on the inheritance and development of the contemporary Sichuan School Guqin.The analysis results are consistent with the conclusions of existing academic research,which proves that the knowledge graph can provide quantitative analysis tools for the influence research of core figures,enrich the research methods of the Sichuan School Guqin.

5. Discussion

5.1. Innovation Points of the Study

Compared with existing research,this study has three obvious innovation points.First,in terms of research perspective,it integrates the perspective of Digital Humanities and knowledge graph technology into the research of the inheritance genealogy of the Sichuan School Guqin,breaking through the limitations of traditional research methods that rely on textual description,and providing a new research paradigm for the digital protection of the Sichuan School Guqin.Second,in terms of modeling methods,a multi-dimensional relationship modeling system integrating"nodes-relationships-time"is constructed,and the"Heritage Branch"node and"INFLUENCED"relationship are added,which can accurately depict the inheritance characteristics of the Sichuan School Guqin such as"parallel development of multiple branches"and"implicit artistic exchanges",making up for the deficiency of existing general

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knowledge graph frameworks that cannot adapt to the unique inheritance characteristics of the Sichuan School Guqin.Third,in terms of technical optimization,the Neo4j database index is optimized by combining single-attribute indexes and composite indexes,which significantly improves the query efficiency of the knowledge graph,and solves the practical problems of slow query and low efficiency in the research of the inheritance genealogy of the Sichuan School Guqin.

5.2. Limitations of the Study

Although this study has achieved certain research results,it still has some limitations.First,in terms of data coverage,the current knowledge graph mainly covers the core figures and inheritance relationships of the Ye Family Branch and the Gu Family Branch,and the data coverage of other small inheritance branches of the Sichuan School Guqin is insufficient.This is because the relevant research literature of small branches is scarce,and it is difficult to collect sufficient data.Second,in terms of relationship types,the current knowledge graph mainly defines three types of core relationships,and the description of other types of relationships(such as the relationship between inheritors and Guqin scores,the relationship between inheritors and performance activities)is insufficient,which limits the comprehensiveness of the inheritance network.Third,in terms of application scenarios,the current application verification is mainly focused on academic research scenarios,and the application exploration in practical scenarios such as cultural dissemination and popularization is insufficient.

5.3. Future Optimization Directions

In response to the above limitations,this study proposes three future optimization directions.First,expand the data coverage.Through in-depth field investigations and additional expert interviews,collect data on small inheritance branches of the Sichuan School Guqin,supplement the nodes and relationships of the knowledge graph,and improve the comprehensiveness of the inheritance network.Second,enrich the relationship types.Increase the relationship types such as"CREATED_SCORE"(relationship between inheritors and Guqin scores)and"PARTICIPATED_ACTIVITY"(relationship between inheritors and performance activities),and construct a more comprehensive inheritance network that integrates"figures-branches-scores-activities".Third,expand application scenarios.Combine digital visualization technology to develop a visual exhibition platform for the inheritance genealogy of the Sichuan School Guqin,realize the popularization and dissemination of the Sichuan School Guqin culture;cooperate with intangible cultural heritage protection institutions to apply the knowledge graph to the daily management and protection work of intangible cultural heritage,and give play to the practical value of the knowledge graph.

6. Conclusion

This study takes the inheritance genealogy of the Sichuan School Guqin as the research object,constructs a multi-dimensional relationship knowledge graph based on the Neo4j graph database from the perspective of Digital Humanities,and completes the research on the construction and application of the knowledge graph.The main research conclusions are as follows:

First,a multi-dimensional knowledge graph model for the inheritance genealogy of the Sichuan School Guqin centered on"core figures-inheritance branches"is constructed.The model includes two types of core nodes(Key Person,Heritage Branch)and three types of core relationships(TEACHER_OF,BELONGS_TO,INFLUENCED),and embeds temporal dimensions to realize the structured semantic representation and temporal evolution characterization of the inheritance genealogy.

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Second,the batch construction of the knowledge graph is completed through data collection and preprocessing,data format conversion,and batch import.The constructed knowledge graph includes 68 core figure nodes,2 inheritance branch nodes,and 92 relationships,with high data completeness and accuracy(coverage rate of classic literature content≥95%,error rate≤5%).

Third,the index optimization scheme of the Neo4j database is designed,which significantly improves the query efficiency of the knowledge graph.The average response time of typical query scenarios is reduced by more than 80%,which can meet the efficient retrieval needs of academic research.

Fourth,the constructed knowledge graph has important application value in academic research.It can realize efficient traceability of inheritance chains and quantitative analysis of core figure influence,providing a new digital tool for the research of the Sichuan School Guqin.

The research results of this study not only enrich the theoretical system of the digital protection of intangible cultural heritage,but also provide a reusable technical path for the construction of inheritance genealogies of similar traditional art schools.In the future,through the expansion of data coverage,the enrichment of relationship types,and the expansion of application scenarios,the research results will be further improved and applied,contributing to the digital protection and sustainable development of the Sichuan School Guqin and other traditional cultural heritages.

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