APPLICATION AND PLATFORM DESIGN OF SPATIOTEMPORAL DATA OPENING AND SHARING

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ABSTRACT:

Spatiotemporal data is data that has both temporal attributes and spatial distribution. The core of the opening and sharing of spatiotemporal data is to exchange, share and collaborate with various data, including spatiotemporal data, based on a unified spatiotemporal benchmark. The research methods of domestic and foreign scholars on the opening and sharing of spatiotemporal data mainly focus on spatiotemporal data model, database research, big data mining analysis and visual expression. This paper introduces the connotation and current situation of open sharing of spatiotemporal data. The typical applications of spatiotemporal data open sharing are listed and summarized. This paper proposes to build an open sharing platform for spatiotemporal data, and gives the basic requirements of four parts: spatiotemporal benchmark, spatiotemporal modeling big data, cloud computing-based spatiotemporal big data system and supporting environment. Taking the National Platform for Common Geospatial Information Services (TIANDITU) as an example, the main indicators of the spatiotemporal data open sharing platform are given. Finally, the article concludes and points out the opportunities and challenges faced by the open sharing of spatiotemporal data. In order to play a greater role in social public application services and administrative decision-making.

1. INTRODUCTION

Spatiotemporal data has the characteristics of spatial, temporal, multidimensional, massive, and complex compared with non-spatial data. Spatiotemporal data occupies a certain spatial distribution in its corresponding spatial dimension, is only valid for a period of time, and changes with time. The value of spatiotemporal data lies in the relationship between time, space, and objects. Spatiotemporal data mainly comes from the parts of geospatial big data with spatiotemporal characteristics, and there are also data from the spatiotemporal media of social activities, such as mobile phone communication signalling and social network media. Big data itself occurs in a certain time and space, and is essentially spatiotemporal big data. However, in general big data research, the spatiotemporal characteristics of big data are not clearly defined, but the geographic element data is used as the background (equivalent to the geographic base map of thematic map), this is just the integration of big data statistical analysis and visualization of mining results; while spatiotemporal data emphasizes the spatiotemporal characteristics of big data as the object of analysis and mining, and the analysis and mining process are all carried out in time and space. The result of analysis and mining itself reflects the time change trend and the spatial distribution law.

This paper firstly presents the connotation and status quo of the opening and sharing of spatiotemporal data. Secondly, on the basis of enumerating and summarizing the typical applications of spatiotemporal data open sharing, it proposes to build a spatiotemporal data opening and sharing platform, mainly designing the basic requirements and indicators of spatiotemporal benchmark, spatiotemporal modeling big data, cloud computing-based spatiotemporal big data system and supporting environment 4 parts. Thirdly, a design example of spatiotemporal data opening and sharing platform is given. The article summarizes the opportunities and challenges faced by the open sharing of spatiotemporal data, mainly focusing on institutional mechanisms, building spatiotemporal information infrastructure, and establishing a security guarantee system at last. The article concludes with a summary and acknowledgment of the full text.

2. RELATED WORK

The research methods of domestic and foreign scholars on the opening and sharing of spatiotemporal data mainly focus on:

Spatiotemporal data model. The concept of spatiotemporal data model was first proposed by R. F. Tomlison in 1963 with the definition of Geographic Information System (GIS). It is the method and theoretical basis for GIS software to organize and manage spatial data; in the early 1970s, many domestic and foreign researchers developed Research on the description and representation of time semantics; Langran G. (1992) put forward the concept of TGIS in his doctoral dissertation "Time in Geographic Information System", focusing on the study of the semantics of time and space, topological relations, query language, evolution and deduction, and time and space Basic theories such as data models; then to the beginning of the 21st century, foreign scholars such as Peuquet, Pelekis, Worboys, and domestic researchers represented by Chen Jun, Huang Mingzhi, Gong Jianya, Shu Hong, Zhang Zuxun, Huang Xingyuan, etc. Proposed spatiotemporal data models with different focuses, such as spatiotemporal cube model, sequence

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snapshot model, ground state correction model and spatiotemporal composite model.

Spatiotemporal database research. In the mid-1980s, based on the spatiotemporal data model, the integration and fusion of temporal semantics and database technology was carried out. Research on spatiotemporal databases and their query languages was in the ascendant, such as non-uniform event database (J. Ben-Zvi et al., 1982), object history model (S. Ginsburg, 1983), time dimension (transaction time, effective time) and temporal query languages TQuel (R. Snodgrass, 1984), two spatiotemporal databases based on raster and vector data (Armstrong, 1988). Since the 21st century, along with the concept of "big data", big data technology with massive multi-source heterogeneous data as the main research object has been widely used, among which a large number of "spatiotemporal big data" concepts related to spatiotemporal location have emerged. Academicians Li Deren (2016), Wang Jiayao et al. (2017) and other academicians believe that spatiotemporal big data refers to the integration of big data and geographic spatiotemporal data.

Spatiotemporal big data mining analysis and visual expression. Academician Li Deren et al. (1995) took the lead in advocating the discovery of knowledge from GIS databases; Harvey et al. (2009) proposed "Geographic Data Mining and Knowledge Discovery", which marked the essence of spatiotemporal data and data mining technology Sexual cross. Wang Jinfeng et al. (2014) summarized seven main methods of spatiotemporal data analysis. Academician Li Deren et al. (2015) took the lead in proposing the realization of global social and economic dynamic monitoring supported by remote sensing marketing based on remote sensing big data.

3. APPLICATIONS OF SPATIOTEMPORAL DATA OPENING AND SHARING

The open sharing of spatiotemporal data is mainly used in spatiotemporal big data platforms and digital city construction.

3.1 Spatiotemporal big data platform

The spatiotemporal big data platform generally include big data centers, shared service platforms, etc., such as the National Earth System Science Data Center (NESSDC) and the Big Earth Data Science Engineering Project (CASEarth), etc.

3.1.1 Data Sharing Service Platform by NESSDC: relying on the institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences. At present, China has initially realized the sharing of Earth system scientific data, as shown in Figure 1.

Figure 1. Data Sharing Service Platform by NESSDC. (http://www.geodata.cn/)

The data center conducts independent processing and integration of data resources at the multi-level of "sphere system-discipline classification-typical area", and has been built covering the atmosphere, hydrosphere, cryosphere, lithosphere, land surface, ocean and outer space The 18 first-level disciplines have a wide range of disciplines, multiple temporal and spatial scales, and the largest comprehensive Earth system science database group in China. There are 115 subject databases in multi-disciplinary fields such as development and utilization, earth observation and navigation (water, soil, gas, raw materials, minerals, energy, etc.), more than 35,000 open and shared datasets, and more than 2.14PB of data resources.

3.1.2 Data Sharing and Service Portal by CASEarth: is built for the release and sharing of data resources of "Big Earth Data Science Engineering Project" launched by the Chinese Academy of Sciences, as shown in Figure 2.

Figure 2. Data Sharing and Service Portal by CASEarth. (https://data.casearth.cn/)

The system provides a variety of data discovery modes such as item classification, keyword retrieval, tag cloud filtering, data association recommendation, etc. for special data characteristics; provides online download, API interface access and other data acquisition modes; supports customizable multi-format data online View, preview and query; support personalized demand-oriented statistics, collection, recommendation, download, and evaluation services.

3.2 Digital City

Another major application of open sharing of spatiotemporal data is digital city construction, including Smart City, Digital Twin City, 3D Real Scene City, etc.

3.2.1 Smart City: Academician Deren Li pointed out that Smart City equal to digitalization plus Internet of Things (IoT) plus cloud computing.

Figure 3. Intelligent supervision platform for household garbage by Smart Deqing. (http://61.175.121.72:3300/app/index.html)

As shown in Figure 3, Smart Deqing creates smart city management based on the open sharing of spatiotemporal data, sensing, analyzing, and integrating various key information of the core system of urban operation, so as to provide information on people's livelihood, environmental protection, public safety, urban services, and industrial and commercial activities. Respond intelligently to various needs within. It realizes the intelligent management and operation of the city, and then creates a better life for the people in the city and promotes the harmonious and sustainable development of the city.

3.2.2 3D Real Scene City: is an important new infrastructure as a real, three-dimensional, time-sequential reflection of human production, life and ecological space. Interconnection provides a unified spatial positioning framework and analysis basis for digital cities, and is an important strategic data resource and production factor for digital government and digital economy.

Figure 4. The 3D Real Scene of Jiangshan City.

As shown in Figure 4, the 3D real scene of Jiangshan City is based on the electronic map and remote sensing image of the National Platform for Common Geospatial Information Services (TIANDITU). Through the construction of the three-dimensional database, the data sharing and exchange with the "Digital Jiangshan" sharing service platform and the national "TIANDITU" are realized. Through multi-department sharing and collaboration, gradually realize and improve multi-platform and multi-department data sharing, apply advanced oblique photogrammetry, 3D GIS and other technical means to build 3D landscape base maps, and integrate with 3D terrain landscapes to reproduce the scenery of the landscape. The characteristic three-dimensional scene provides a three-dimensional base for the digital reform and social governance modernization of Jiangshan City.

4. DESIGN OF THE INTEGRATED SPATIOTEMPORAL DATA OPENING AND SHARING PLATFORM

The spatiotemporal data opening and sharing platform mainly includes: spatiotemporal benchmark, spatiotemporal modeling big data, cloud computing-based spatiotemporal big data system and supporting environment, as shown in Figure 5.

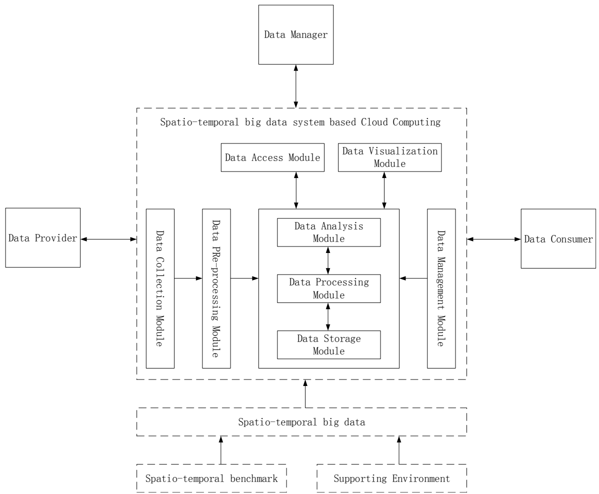

Figure 5. Overall functional architecture of the spatiotemporal data opening and sharing platform.

4.1 Spatiotemporal benchmark

The spatiotemporal benchmark is the basic reference basis and the starting data for the measurement in the time and geospatial dimensions.

The date in my country's time datum adopts the Gregorian calendar era, and the time adopts Beijing time; the geodetic datum adopts China Geodetic Coordinate System 2000 (CGCS2000), and the elevation datum adopts the 1985 national elevation datum.

4.2 Spatiotemporal modeling big data

Spatiotemporal modeling big data is related data sequenced and modeled according to a unified spatiotemporal benchmark. The basic components include geomatics information data, earth system scientific data, natural resource business data, mobile phone signaling data, social network check-in data, public thematic data, intelligent perception data, etc.

The steps of spatiotemporal modeling data generation include: intelligent perception and acquisition; distributed computing and storage; mining, knowledge discovery and visualization, etc.

4.2.1 Intelligent perception and acquisition: are the primary conditions for the open sharing of spatiotemporal big data. On one hand, the intelligent perception and acquisition of spatiotemporal data relies on the massive sensors in the Internet of Things (IoT), including video sensors, mobile sensors, RFID sensors, traffic sensors, and aerial photography sensors. On the other hand, it mainly comes from basic geographic information data including vector data, image data, terrain data, 3D model data, etc.; thematic and application data; crowdsourcing data, etc.

4.2.2 Distributed computing and storage: including spatiotemporal big data organization and management, parallel computing, distributed storage and retrieval, and other key technologies.

Spatiotemporal Big Data Organization and Management (O&M): Traditional metadata, relational databases and other data organization and management methods can no longer meet the challenges of massive, multi-source, heterogeneous, real-time, high concurrent access and high scalability of spatiotemporal big data. Therefore, the composition of geospatial entities should be simplified to the minimum logic. Unit-Meta-Semantic object, design a spatiotemporal data model of geographic meta-semantic object based on Hadoop, and adopt the distributed storage and retrieval method of geographic spatiotemporal data to realize the organization and management of spatiotemporal big data.

Parallel Computing (PC): is one of the effective ways to solve the excessive time-consuming numerical operation of spatiotemporal big data. For example, the MapReduce parallel computing module.

Distributed Storage and Retrieval (DSR): that is, the real-time data storage and retrieval mechanism with multiple copy management functions is distributed on multiple computing and storage nodes through the computer network to meet the efficient storage and fast retrieval of massive data resources. For example, combining the Hadoop distributed computing open source framework and HBase column storage database.

4.2.3 Mining, knowledge discovery and visualization: is the ultimate purpose of spatiotemporal modelling big data including mining and analysis, knowledge discovery in database, and data visualization.

Mining and Analysis (MA): refers to the use of machine learning, data mining, pattern recognition and other methods to extract knowledge or patterns for specific application targets after completing spatiotemporal big data preprocessing. There are two types of mining analysis services, one based on Spark Streaming and one based on Spark Core. Read data from the specified HDFS file for mining analysis. The main form is Spatial Analysis, and data interaction is realized through Kafka message queues.

Knowledge Discovery in Database (KDD): is an important part of spatiotemporal big data knowledge service and an important link connecting resources and users. The main content is a complex process of identifying those valid, novel, potentially useful, and ultimately understandable patterns from spatiotemporal big data.

Data Visualization (DV): is multi-dimensional spatiotemporal information visualization, the main forms are Tables, Histograms, Pie Charts, Line Charts, Heat Map, etc.

4.3 Cloud computing-based spatiotemporal big data system

Cloud computing-based spatiotemporal big data system is built on a Service-Oriented Architecture (SOA) based on network/grid services, based on spatiotemporal big data and supported by cloud computing environment, relying on ubiquitous network, distributed computing and storage resources to provide data, functions, interfaces and basic open information systems such as knowledge services. The basic components include portal website, cloud service system, service engine, etc.

4.3.1 Portal website: is an application system that provides comprehensive Internet information resources and information services related to the open sharing of spatiotemporal data, and at least two modules search engine and directory service should be included.

Search Engine (SE): provides users with search query services through the website. It is mainly composed of four parts: a crawler that finds and crawls information, an indexer that indexes the crawled spatiotemporal data, a crawler that retrieves the indexed content, and a User Interface (UI) where users can enter query information.

Directory Service (DS): the spatiotemporal data resource provider registers, publishes and manages resources through the catalog, and the demander searches and obtains the resources through the catalog. The basic functions include catalog content cataloging, registration, publishing, query and maintenance. It includes 2 modules of spatiotemporal metadata and data resource directory service.

4.3.2 Cloud service system: provides computing and storage resource pool services based on cloud computing technology. Clients can access the cloud service subsystem through the network anytime and anywhere to provide various services, such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS) and Data as a Service (DaaS).

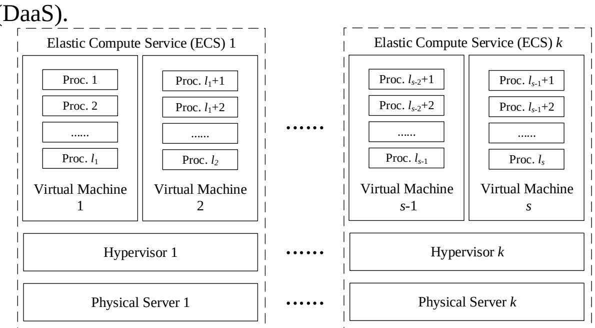

Figure 6. Architecture of Cloud Service System Resource Pool.

As shown in Figure 6, the cloud service system resource pool provides computing and storage resources. Suppose a resource pool consists of an application with l processes and s cloud virtual institutions deployed on K Elastic Cloud Server (ECS) nodes As a result, each node runs a hypervisor and a different number of cloud virtual machines. When any node or software component fails, the system will also fail. In the case of a hardware node failure, the failed node will be replaced by a new node and the system will be restarted; and in the case of a software component failure, the cloud virtual machine will be restarted and the system will continue to run.

4.3.3 Service engines: includes place-name and address engine, data flow engine, business flow engine, knowledge engine and service management background.

Address Engine (AE): it can realize precise positioning of massive, multi-source, heterogeneous spatiotemporal big data on the full-spatial information model, including forward/reverse geocoding and place name retrieval services. Among them, geocoding converts the geographic location information describing addresses into geographic coordinates that can be used in GIS, and the uncertainty of matching results is greatly affected by the capacity and data quality of the geographic name address database; Retrieval of entity proper nouns to obtain their spatial coordinates and social attribute information.

Data Flow Engine (DFE): includes various data APIs such as geomatics frame, DOM, DLG, DRG, and DEM data.

Business Flow Engine (BFE): under the basic positioning of "two services and two supports" for natural resources, it serves natural resources business and work management. Including providing services in various fields such as natural resource survey and monitoring, national land space planning, cultivated land protection, ecological protection and restoration, and real estate registration.

Knowledge Engine (KE): organize and associate spatiotemporal knowledge through a unified spatial reference frame, and transform it into a spatiotemporal knowledge resource to provide services collaboratively. It has basic functions such as knowledge browsing, question and answer, search, and recommendation, and also provides descriptive, diagnostic, predictive, and program-based knowledge services.

Service Management Background (SMB): for various management users, realize the management of registration, authentication, monitoring, equipment, terminal applications, authorization codes, and interfaces of various service engines.

4.4 Supporting environment

Supporting environment of supporting open sharing of spatiotemporal data includes hardware and software infrastructure, security and confidentiality system, sefety operation and maintenance management system standards specification, etc.

4.4.1 Hardware and software infrastructure: physical facilities, computing resources, storage resources, network resources, databases, memory, I/O devices, cloud servers, cloud storage devices, cloud transmission devices, and network devices are included in the traditional or cloud computing IDC (Internet Data Center) rooms.

4.4.2 Security and confidentiality system: it meets the requirements of level 3 or above of national network security protection (GB/T 22239-2019), and meets the basic requirements of state secrecy (BMB17-2006, BMB20-2007).

4.4.3 Safety operation and maintenance management system standards specification: it includes security incident management, system and application management, network management, storage backup management, fault management, technical support tool management, personnel management, quality and assessment management, etc.

4.5 An example of spatiotemporal data opening and sharing platform design

The National Platform for Common Geospatial Information Services (TIANDITU) is a networked geographic information opening and sharing service portal constructed by the National Geomatics Center of China, as shown in Figure 7.

Figure 7. The National Platform for Common Geospatial Information Services (TIANDITU).

The geographic information public service resources of enterprises, institutions, social organizations, and the public provide authoritative, standardized, and unified online geographic information comprehensive services to all types of users. At present, a new generation of spatiotemporal data open sharing platform is being built. The detailed indicators of TIANDITU are shown in Table 1:

System	Index Item	Detailed Design Content
Spatiotemporal Benchmark	Spatiotemporal Benchmark	Date: Gregorian era; Time: Beijing time; Geodetic Datum: China Geodetic Coordinate System 2000 (CGCS2000); Elevation datum: 1985 National Elevation Datum.
Spatiotemporal Modeling Big Data	Intelligent Perception and Acquisition	Temporal and spatial data are mainly from geomatic data submitted by national, provincial and city (county) level data center nodes, thematic data shared and exchanged by other sectors of the industry, and crowdsourced data uploaded by the public.
	Distributed Computing and Storage	Docker technology is used for distributed computing; MongoDB and HBase Database is used for distributed storage.
		Services Center: Release topics based on the Spark;

	Mining, Knowledge Discovery and Visualization	Data Manager: Support data upload and spatial conversion in csv, shp, geojson and other formats, and online editing and management of data; Thematic Layer: meet the application needs of government and industry departments for personalized maps and thematic maps; Data Visualization: Support OCG WMS, WMTS and vector tile map service overlay.
Spatiotemporal Big Data System based on Cloud Computing	Portal Website	National and provincial nodes domain name: htttps://*.tianditu.gov.cn
	Cloud Service System	Deployed in the public cloud to provide external public map services, deployed in the private cloud to provide data production services, and built a cloud service system based on a hybrid cloud architecture
	Service Engines	Support IP/Cookie/Referer based multi-dimensional CC protection
Supporting Environment	Supporting Environment	Hardware and software infrastructure: IaaS Mode; Security and confidentiality system: meet the requirements of level 3 of national network security protection and basic requirements of state secrecy; Safety operation and maintenance management system maintenance standards: More than 30 regulations.

Table 1. The detailed indicators of TIANDITU.

5. CHALLENGES AND OPPORTUNITIES OF SPATIOTEMPORAL DATA

5.1 Strengthen the open sharing of spatiotemporal data

Due to historical reasons such as institutional mechanisms, the opening and sharing of spatiotemporal data is currently facing great obstacles. Measures must be taken from the reform level to effectively promote the opening and sharing of spatiotemporal data:

The first is government leadership. Governments at all levels must fully understand the openness and sharing of spatiotemporal data, lead the establishment of various inter-governmental spatiotemporal data resource coordination agencies, involve all government departments and non-governmental organizations, formulate coordination rules, and provide policy support.

The second is cross-industry collaboration. The natural resource department is the provider of spatiotemporal data resources but not the only resource user. In the open sharing of spatiotemporal data, the resource application party should be the leader, the resource provider should cooperate, and policies should be issued to enable the two parties to collaborate and share resources across industries. I, I have your pattern.

The last is cross-system operation. More spatiotemporal data application resources are in the hands of enterprises, institutions, crowdsourcing enthusiasts, etc. Government departments should break down institutional barriers and realize data acquisition, exchange and marketing service models between spatiotemporal data producers and other government departments and private institutions. , to realize the open sharing of spatiotemporal data to truly provide services to the public, and at the same time, private institutions themselves also gain profits and develop.

5.2 Building spatiotemporal information infrastructure

The spatiotemporal information infrastructure is an indispensable and basic information resource for the spatiotemporal big data platform and digital cities. The open sharing of spatiotemporal data should be based on the construction of spatiotemporal information infrastructure. The spatiotemporal information infrastructure constitutes a spatiotemporal data open sharing platform and a spatiotemporal knowledge center.

The spatiotemporal data open sharing platform includes spatiotemporal benchmark, spatiotemporal modeling big data, cloud computing-based spatiotemporal big data system and supporting environment, and its core content is spatiotemporal modeling big data and cloud computing-based spatiotemporal big data system.

Based on the concept of spatiotemporal knowledge base, the spatiotemporal knowledge center builds a service platform or environment for the acquisition, accumulation, creation, evolution and utilization of spatiotemporal knowledge with the help of professional domain capabilities and professional skills such as spatial analysis and spatial mining, and provides intelligent knowledge evolution and in-depth knowledge services.

5.3 Establish an integrated security system

The open sharing of spatiotemporal data is inseparable from network security, data security and information confidentiality technologies. An integrated security guarantee system should be established from the four levels of people, systems, technology and management.

People: Strengthen the security risk awareness of decision makers and industry users, continuously improve the skills and levels of professional and technical personnel, and strengthen education and training on network security and confidentiality awareness.

System: On the basis of meeting the compliance standards of network security level protection (GB/T 22239-2019) and Information System Assurance Evaluation (GB/T 20274) compliance standards strengthen the construction of safety operation and maintenance system, and establish a sound safety guarantee system.

Technology: Continuously apply new cyberspace security technologies such as trusted computing and zero trust to effectively ensure network security, the security of the full life cycle of spatiotemporal data, and the security of personal information.

Management: The open sharing of spatiotemporal data should follow the requirements of ISO/IEC 27001 information security management system to ensure the confidentiality, integrity and availability of information.

6. CONCLUSION

To sum up, with the continuous development of information technology, the opening and sharing of spatiotemporal data is an inevitable trend, and the opening and sharing of spatiotemporal data will play a huge role in social public application services and government affairs management decision-making. In the future, on the one hand, it is necessary to further strengthen the opening and sharing of spatiotemporal data; on the other hand, it is necessary to speed up the construction of an open and sharing platform for spatiotemporal data, combine industry and application data, increase efficiency and speed up the development of the digital economy, and provide correct guidance and decision-making assistance for supporting social governance.

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