Application and Platform Design of Geospatial Big Data

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ABSTRACT:

With the wide application of Big Data, Artificial Intelligence and Internet of Things in geographic information technology and industry, geospatial big data arises at the historic moment. In addition to the traditional "5V" characteristics of big data, which are Volume, Velocity, Variety, Veracity and Valuable, geospatial big data also has the characteristics of "Location Attribute". At present, the study of geospatial big data are mainly concentrated in: knowledge mining and discovery of geospatial data, Spatiotemporal big data mining, the impact of geospatial big data on visualization, social perception and smart city, geospatial big data services for government decision-making support four aspects. Based on the connotation and extension of geospatial big data, this paper comprehensively defines geospatial big data comprehensively. The application of geospatial big data in location visualization, industrial thematic geographic information comprehensive service and geographic data science and knowledge service is introduced in detail. Furthermore, the key technologies and design indicators of the National Geospatial Big Data Platform are elaborated from the perspectives of infrastructure, functional requirements and non-functional requirements, and the design and application of the National Geospatial Public Service Big Data Platform are illustrated. The challenges and opportunities of geospatial big data are discussed from the perspectives of open resource sharing, management decision support and data security. Finally, the development trend and direction of geospatial big data are summarized and prospected, so as to build a high-quality geospatial big data platform and play a greater role in social public application services and administrative management decision-making.

1. INTRODUCTION

Geographical Information is an important basic and strategic information resource for the country, which involves economic and social development, ecological civilization construction, national security and people's life facilitation. It is playing an increasingly important role in digital economy, government decision-making, industrial development and people's life. With the development of Big Data, Artificial Intelligence and other technologies, the huge amount of geospatial data generating in the application of geographic information forms the rudimentary form of geospatial big data.

Scholars' studies on geospatial big data mainly focus on:
Knowledge mining and discovery of geospatial data: academician Li Deren has took the lead in international research on the nature of geospatial data knowledge mining, pioneered the discovery of knowledge from GIS databases, and published the monograph "*Spatial Data Mining Theory and Application*" in 1995. Harvey proposed "*Geographic Data Mining and Knowledge Discovery*" for the first time in 2009. There is a paper which further expounds the characteristics of big data GIS from three aspects of GIS spatial data management, spatial data analysis and visualization (Li Qingquan et al., 2014). They put forward the concept of big data generalized GIS, and further elaborated the characteristics of big data GIS from the three aspects of GIS spatial data management, spatial data analysis and visualization. The integration trend of geographic computing, urban computing and social computing in the era of generalized GIS is forecasted (Lu Feng et al., 2014; Mccoy et al., Soille et al., 2017).

Spatiotemporal big data mining: Li Deren believes that spatiotemporal data mining is a process of automatically discovering and extracting implicit and non-visible patterns, rules and knowledge from massive and multi-source spatiotemporal big data. The techniques are analyzed to discover knowledge from spatial big data (Praveen et al., 2016), and to further make knowledge change into data intelligence (Wang Shuliang et al., 2013; Shekhar et al., 2015). Songnian Li classified and summarized the geographic big data mining methods from the perspective of mining targets in 2015. Bian Fuling discussed the latest research progress of spatial big data mining from two aspects of platform and algorithm in 2017. Another five attributes except for "5V", including granularity, scope, density, skewness and precision, are summarized regarding geospatial big data (Mir et al., 2018; Pei Tao et al., 2019).

The impact of geospatial big data on visualization, social perception, smart city, etc: some people believe that the new technical features of geospatial big data will promote the new development of map synthesis, map visualization and map projection (Kramer et al., 2015; Ai Tinghua, 2016). Liu Yu believe that multi-source geographic big data provides an unprecedented means of social perception for the distribution pattern, interaction and dynamic evolution of geographical phenomena in 2018. Academicians such as Li Deren and Wang

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Jiayao believed that without geospatial big data, there would be no smart city.

Geospatial big data services for government decision-making support: Liu Jiping believes that geospatial big data technology oriented to e-government provided a new means for government information management and decision-making in 2014. The FogGIS (which is a geographic information system based on fog calculation method) is proposed to government geospatial health big data analysis and coastal risk adaptation (Rumson et al., 2017; Barik et al., 2016; Barik et al., 2019).

In brief, this paper is organized as follows: Section 2 gives the connotation of geospatial big data at first. Section 3 introduces the application of geospatial big data, while the key technologies and design are introduced in Section 4 which mainly contains the infrastructure, functional and non-functional basic requirements and indicators of the National Geospatial Big Data Platform, and gives a practical example. Section 5 summaries the opportunities and challenges of geospatial big data. We conclude our paper in Section 6.

2. CONCEPT OF GEOSPATIAL BIG DATA

Geographical spatial scope of big data: including the geographic location of the geographical space (mainly refers to the surveying and mapping geographic information, without geography, geology) location data and business data, such as economy and society not only has the property of common data measured value (V), but also contains the time (T) and space (X, Y, Z) information, with the characteristics of space, time, attributes, 3d. Geographical spatiotemporal data constitute the era of big data describing various features and phenomena of space frame and space benchmark (basic geographic information), moreover, contains the surface features and economic and social activities of time and space distribution. As an important data type, geographical spatiotemporal data has "5V" characteristics like as a traditional big data, and geographical "Location Attributes" (Location). It is mainly divided into two categories:

Geospatial basic big data: basic geospatial big data mainly includes vector data, raster data, map tile data and remote sensing image data from mapping and remote sensing. Basic geographic data as a unified framework of spatial orientation and spatial analysis, describes the measurement of the earth's surface control points, drainage, residents and facilities, traffic, pipeline, state and administrative region, landform, vegetation and soil, cadastral management, place names and other information of location, shape and properties on natural and social factors. Basic geographic data has become a kind of important geographic space based large data.

Geospatial applied big data: on the one hand, geospatial applied big data comes from industry data of natural resources, environment, water conservancy, public security, statistics and other departments, such as IoT sensor data collected by water, electrical or mining companies. On the other hand, through organic integration of basic geographic data with natural, cultural, economic and cultural data, it provides correct guidance and decision-making assistance for various industries and forms industrial economic data and historical and cultural data. For example, industrial economic data includes not only GIS, satellite positioning and navigation, aviation and aerospace remote sensing industrial economic data, but also LBS (Location-based Services), geographic information service and other industrial economic data. Historical and cultural data includes historical atlases and national maps.

It is worth mentioning that through the collection, fusion and aggregation of a certain volume of applied big data on the basis of geospatial basic big data, a complete geospatial big data is formed, which provides the basic data source for the following geospatial big data application, national spatial information infrastructure platform, project information system, etc.

3. APPLICATIONS OF GEOSPATIAL BIG DATA

The geospatial big data is widely used in the Internet, Mobile Internet, Internet of Things and other scenarios. At present, the application fields of geospatial big data are mainly divided into geospatial location visualization, industrial thematic geographic information integrated services, geographic data science and knowledge service research.

3.1 Visualization of geospatial locations

The visualization of geospatial position mainly includes map visualization, GIS visualization and graph visualization.

3.1.1 Map visualization: map means describing spatial elements with symbols, and using cartographic theory to express the representation of the earth on the plane. Map visualization is to express geospatial phenomena and laws by transforming geospatial location data into visible static two-dimensional symbols. Figure 1 shows the global COVID-19 epidemic distribution map.

Figure 1. The global COVID-19 epidemic distribution map.

3.1.2 GIS visualization: Geographic Information System (GIS) is a technical system that collects, stores, manages, calculates, analyses, displays and describes the geographic distribution data in the whole or part of the earth's surface (including the atmosphere) with the support of computer hardware and software systems. GIS visualization focuses on geoseological data model and structure design, dynamic multi-dimensional data display, cultural and economic spatial regional data visualization, etc., and its visualization analysis results are also expressed in the form of maps.

3.1.3 Visualization of charts and graphs: graph visualization includes line graph, histogram, bar graph, pie graph, line graph, rectangular tree graph, curved surface graph, scatter graph, parallel coordinate graph and radar graph. Graph visualization includes density map, heat map, vector rectangular grid map, vector hexagonal grid map, linkage map and vector polygon thematic map.

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3.2 Comprehensive services of industrial thematic geographic information

Comprehensive services of industrial thematic geographic information integrates information sharing, data publishing and functional service. It also realizes the efficient and accurate collection of geographic information data from non-surveying and mapping geographic information industry sectors. Besides, it realizes the integrated application display of industrial thematic data and geospatial big data. For a long time, geographic information has been deeply applied in the fields of natural resources, water conservancy, transportation, public security, safety and emergency response, ensuring efficient and high-quality integrated industrial thematic geographic information services. Here are four examples:

Emergency industry: the National Emergency Early Warning Information Publishing Network comprehensively displays the early warning information of 76 emergencies in four categories of natural disasters, accidents and disasters, public health events and social security events. The Network provides accurate early warning information services for the state and the public, as shown in Figure 2.

Figure 2. The National Emergency Early Warning Information Publishing Network map.

Meteorological industry: China Central Meteorological Observatory provides real-time weather information and services for 60,000 cities, towns, scenic spots, airports, islands, ski resorts and golf courses at home and abroad. Figure 3 shows the generation track and real-time location of typhoon No. 2102 SURIGAE on the typhoon website.

Figure 3. Generation track and real-time location of typhoon No. 2102 SURIGAE on the typhoon website.

Natural Resources industry: the geological cloud system portal which developed by the China Geological Survey of the Ministry of Natural Resources, integrates the massive geological survey data formed by the national geological work since the founding of the People's Republic of China—oil and gas, minerals, energy resources, mineral resources, as well as the scientific data of geological environment and geological disaster survey. Figure 4 shows the reserves and distribution of rare earth minerals on a scale of 1:500,000.

Figure 4. The reserves and distribution of rare earth minerals on a scale of 1:500,000 map.

Livelihood Economy: China Land Price Information Service Platform presents real-time data of land auction prices, land price monitoring indicators and transaction facts across the country, as shown in Figure 5.

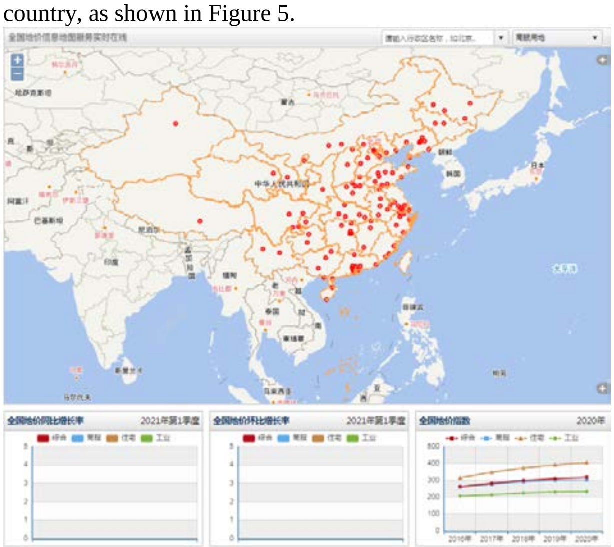

Figure 5. The National land price monitoring and trading reality map.

3.3 Research on geographic data science and knowledge services

As an important part of Earth big data, geospatial big data has always been highly concerned by researchers. The Earth Big Data Science Project led by academician Guo Huadong is based on Earth big data analysis, including geospatial big data, to study the association and coupling of the earth system, understand the complex interaction and evolution process between the earth natural system and human social system, and realize the Sustainable Development Goals (SDGs) (Guo Huadong et al., 2018).

Based on the background of spatio-temporal big data, Academician Chen Jun, a member of the team, discussed the connotation, times characteristics, structure and research direction of geographic knowledge engineering (Chen Jun et al., 2019a). Based on massive basic geographic data, they puts forward the general idea of basic geographic knowledge service with important features of structuralization and correlation, and takes GlobeLand30 (which is a set of high-resolution global land cover data products, covering the land range of 80 degrees north and south latitude, including 10 categories of land cover information, such as cultivated land, forest, grassland and shrub land) knowledge service as an example to introduce the preliminary research progress (Chen Jun et al., 2014). They also developed and launched geographic information professional knowledge service system. The system gathers the geographical information metadata professional literature, public version of basic geographic information data, basic geographic information resources directory, global surface coverage data, statistical analysis and structured, the spatial knowledge modelling and other data resources. The system also provides the latest public version of the geographic information data, thematic maps, free download service. A number of knowledge applications have been developed and put online to provide services of spatial association, mining, analysis and visualization of geographic information expertise. Chen Jun proposed a new method of monitoring and evaluating SDGs based on geographical data and spatial evidence, which is a comprehensive assessment of the progress of 2030 SDGS based on statistics and geographic information, and completed the world's first comprehensive assessment demonstration for the United Nations 2030 Agenda for Sustainable Development at county level in 2017 (Chen Jun et al., 2019b).

All in all, geospatial big data (including basic big data and applied big data) can obtain more useful value through data mining, knowledge discovery and visualization.

4. DESIGN OF GEOSPATIAL BIG DATA PLATFORM

With the further growth of geographic information engineering requirement, each project information system is independent from each other, leading to information silo and barrier, which seriously hinders the application of geospatial big data. The application of geospatial big data needs to be highly dependent on information system and integrated service platform. By building a one-stop geospatial big data platform, it can effectively break the information island and realize the high-quality application of geospatial big data.

As an important component of the National Spatial Data Infrastructure, the geospatial big data platform should primarily meet the universality requirements of big data system construction, and at the same time meet the characteristics requirements of geospatial big data. At present, there are relevant Chinese National Standards (GB/T 38675-2020 and GB/T 38673-2020) that provide detailed provisions on hardware, software, network, security and other infrastructure, as well as basic functional and non-functional requirements of big data system. Secondly, a big data platform with geospatial application and public service attributes should be designed.

4.1 Infrastructure requirements

The geospatial big data platform infrastructure mainly includes hardware and software systems, networks and security systems that provide basic computing support for spatiotemporal big data storage, processing, analysis and application.

Hardware System: mainly including cell, unit of computing speed, storage unit, high-speed Internet and administrative supervision unit, power unit and structure unit and the cooling unit.

Software System: mainly including the operating system, virtualization software, resource management software and management software of communication.

Network System: have the ability to high availability and high consistency, scalability, and isolation.

Security System: should not be below the levels of network security protection level 3 requirements (GB/T 21028 and GB/T 37973-2019).

4.2 Basic functional requirements

The overall framework of geospatial big data platform function is shown in Figure 6. It mainly includes distributed storage and processing system, analysis system, data collection, pre-processing and visualization system and access management system.

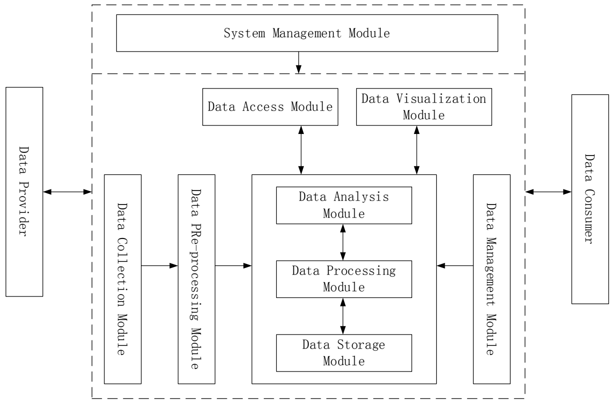

Figure 6. Overall functional architecture of geospatial big data platform.

4.2.1 Storage and Processing System (SPS): the spatiotemporal big data storage and processing system should include storage subsystem and processing subsystem. Common spatiotemporal big data storage and processing systems include HDFS, HBase and Postgres-XL. HDFS is the file system, the query ability is the weakest; HBase is built on HDFS, using column storage, for unstructured data and structured data has a strong query ability. Postgres-XL which is the most query-capable supports complex SQL queries.

Storage Subsystem: providing data storage function, support structured and unstructured and semi-structured data storage; provides the ability to exchange data or files with relational databases and other file systems; supports distributed file storage, distributed column data storage, distributed structured data storage and distributed graph data storage.

Processing Subsystem: supporting batch, stream processing, graph calculation framework; support memory computing, batch stream fusion computing framework; support for automatic scheduling of tasks based on dependencies between tasks.

4.2.2 Analysis System (AS): the temporal and spatial big data analysis system should support data query, machine learning, statistical analysis, offline data analysis, stream data analysis and spatial analysis; support interactive on-line analysis; support for visualize large screen display. This is shown in Table 1.

Functions	Contents
Date Query	track, attributes, mesh, and area of the

	query and summary
Spatial Analysis	spatial location, spatial distribution, spatial relationships and spatial behaviour and process
Statistical Analysis	OD, hot and density analysis, etc.
Machine Learning	anomaly detection, filtering and similar position elements connected
Flow Data Analysis	convection data processing

Table 1. Functions of the AS.

4.2.3 Data collection, Pre-processing and Visualization system (DPV): data collection, pre-processing and visualization system are important parts of big data system. This is shown in Table 2.

Functions	Contents
Data Collection	structured/unstructured/semi-structured/ offline data import
Data Pre-processing	data extraction, data cleaning, line structured data conversion, transformation and table conversion, data loading, etc.
Data Visualization	tables, histograms, pie charts, line charts, heat map, etc.

Table 2. Functions of the DPV.

4.2.4 Access Management System (AMS): big data access management system includes data access, resource management and system management. This is shown in Table 3.

Functions	Contents
Data Access	access interface
Resource Management	CPU, memory, scheduling and configuration, the centralized management of global resources, static resource allocation strategy and dynamic resource allocation strategy, resource flexibility and grab, etc.
System Management	configuration management, tenant management, monitoring alarm management, service management, etc.

Table 3. Functions of the AMS.

4.3 Non-functional basic requirements

The non-functional requirements of geospatial big data platform mainly include reliability, compatibility, security, scalability, maintainability and ease of use.

Reliability: including support for high availability, data redundant storage and distribution of the data backup, recovery and migration, etc.
Compatibility: supporting compatible with different brand operating system.
Security: including support for user management, rights management, log management, data security, etc.
Scalability: including cluster expansion, online and offline capacity, capacity reduction function.
Maintenance: including providing installation deployment management, information system version, online upgrade system, fault diagnosis, all kinds of computing tasks running schedule, status of real-time tracking and reporting, and other functions.
Usability: including system installation configuration tool providing a graphical interface, and complete product documentation.

4.4 An example of geospatial big data platform design

At present, the National Platform for Common Geospatial Information Services as sharing and service portal of geographic information network, has integrated geographic information public service resources of the relevant government departments, enterprises, institutions, social organizations and public, which are from surveying and mapping geographic information departments at various levels (the national, provincial, municipal (county)). The National Platform provides various types of user authority, standard, unified online geographic information integrated service, as Figure 7 shown.

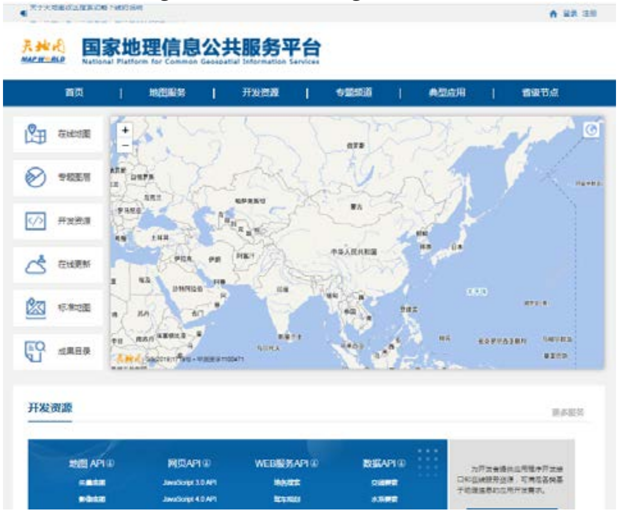

Figure 7. The portal of National Platform for Common Geospatial Information Services.

The value of geospatial big data lies in the application service, and the promotion of geospatial big data application and the provision of geospatial big data service are the important significance of the construction of geospatial big data platform. Therefore, the basic indicators of infrastructure, function and non-function of the big data platform for geographic information public service is shown in Table 4:

Requirement	System	Design Index
Infrastructure Requirements	Hardware System	Each virtual server specifications: CPU ≧ 24 cores, memory ≧ 96GB memory, system disk ≧ 200GB SSD storage of ultra-high performance computing services. Among them, CPU frequency ≧ 3.0GHz, Intranet bandwidth ≧ 12Gbps, Intranet receiving and sending packet ≧ 2 million PPS, disk IO read and write delay ≦1ms
	Software System	Support the virtual server to mount ≧20 data disks, and

		supports the anti-affinity configuration of the virtual server
	Network System	BGP shared bandwidth ≧ 600Mbps, flexible public network IP ≧ 50, enterprise-class VPC public network gateway, maximum number of NAT connections ≧ 50,000, provide NAT agent (SNAT, DNAT), 10Gbps forwarding capacity
	Security System	Enterprise or flagship DDOS high protection, Web application firewall, host security, situational awareness, database security, fortress machine, vulnerability scanning, etc., through the network security level protection level 3
Basic Functional Requirements	SPS	PostgreSQL 10 High Availability Storage Service, Configuration Specifications ≧ 16 Core Memory ≧64GB ≧300GB Solid State Storage Redis 4.0 high availability cache cluster service, each set of Redis memory ≧ 16GB; MongoDB 3.4+ storage service, ≧ 6 shards, each shard provides ≧4TB SSD available storage, each shard specifications CPU≧ 32 core memory ≧128GB, total storage space ≧24TB
	AS	Support full text retrieval capability; Support spatial object, spatial index and spatial operation function for geospatial big data
	DPV	Provide one-click function of computing service image creation, including system disk image, machine image and data disk image enterprise-level data large screen display services
	AMS	Provides efficient collection, transmission and distribution capabilities, and the interface is compatible with Kafka native Producer/Consumer API. Log storage and real-time analysis of 500 million to 700 million visits per day
Non-functional Basic Requirements	Reliability	Provide the backup capability of the whole machine, you can choose the backup time, backup cycle, retention rules
	Compatibility	Distributed OS/database are compatible with the OS/database kernel engine and client
	Security	Support IP/Cookie/Referer based multi-dimensional CC protection
	Scalability	Peak number of concurrent users ≧ 10,000
	Maintenance	7* 24-hour cloud platform monitoring and emergency handling services
	Usability	Provide training service program

Table 4. The basic indicators of the big data platform for geographic information public service.

5. CHALLENGES AND OPPORTUNITIES OF GEOSPATIAL BIG DATA

5.1 Open sharing of geospatial big data

Due to historical reasons for China surveying and mapping geographic information institutions, surveying and mapping achievements of geographic information data scattered in local units which leads to big obstacles to the sharing of data and integration. Therefore, the opening and sharing idea of big data should be followed. We need to set up open geospatial large data sharing mechanism, and establish the geospatial data platform by means of distributed cloud computing technology. On the geospatial data platform, the massive, multi-source and heterogeneous geospatial data can realize collection, integration, processing and application.

The reference framework, specific requirements, openness degree evaluation system and evaluation indicators of government data openness and sharing are stipulated (GB/T 38664-2020). Its core is to build a unified metadata standard, including title, single identifier, category, description, data preview, revision history, license items, label, API authorization items, subsidiary items, etc. (Qian Xiaohong, 2014)

5.2 Decision support for geospatial big data managements

In September 2015, the UN Development Summit adopted the 2030 Agenda for Sustainable Development, which set out 17 Sustainable Development Goals (SDGs) and 169 specific targets covering economic, social and environmental fields. It calls on all countries to achieve coordinated development of economic growth, social inclusion and a better environment by 2030. The Ministry of Natural Resources cooperated with the People's Government of Deqing County in Zhejiang Province to carry out comprehensive monitoring and assessment based on statistics and geographic information in Deqing County as a pilot area, and finally formed the assessment results with "spatio-temporal coordinates" to help the government make accurate decisions and optimize the layout of public facilities (Chen Jun, 2019).

Since the institutional reform, with the depth of the surveying and mapping geographic information business into the Natural Resource Management "Two Unity", points and elements of the management system of grip are gradually broken. The geographical space data contributes to natural resource unified management, supporting unified platform for the decision of the management, and to promoting the modernization of natural resource governance capability.

5.3 Security of geospatial big data

The collection of massive geospatial data makes the internal links such as geospatial big data collection, storage and processing, mining and analysis, and application services face data security risks of data loss, tampering and illegal access. Therefore, data security should be considered from the perspective of the whole life cycle. As an important national strategic resource, geospatial big data faces severe threats to network information security, and its data security is related to national security. Therefore, the security of geospatial big data must be improved from the integration of infrastructure security, network communication security, computing storage and analysis security, management system security and operation and maintenance security of geospatial big data platform.

6. CONCLUSION

To sum up, with the continuous development of information technology, the opening up and sharing of geospatial big data is an inevitable trend. The construction of geospatial big data platform will play a greater role in social public-application service and the administrative management decision-making. In the future, it is necessary to carry out further researches on spatiotemporal big data mining, knowledge service, smart city and perception, etc. Besides, the application of geospatial big data will contribute to providing correct guidance and decision-making assistance for all walks of life.

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