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ORIGINAL RESEARCH ARTICLE

Construction and application of natural resource data governance system

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ABSTRACT

In order to adapt to the construction of ecological civilization and the "two in one" responsibilities of natural resources departments, plus the relevant informatization deployment of the Ministry of Natural Resources, we absorb and summarize the existing informatization experience, and put forward a natural resource data governance system construction idea that meets the actual needs of the administrative departments of natural resources, including the construction of a natural resources data standard specification system, a three-dimensional natural resources "one map" big data system, a space-business-temporal relationship, a distributed data management mechanism, and an update and maintenance mechanism. On the basis of the data governance system, the application direction of in-depth mining, analysis and prediction of natural resources big data is discussed to assist natural resources regulatory decision-making. Finally, a case of using the big data center of the land space basic information platform to support the construction and operation of the natural resource data governance system is introduced.

Keywords: Natural Resources; Data Governance; Big Data; Land Space Basic Information Platform

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1. Introduction

In 2017, the former Ministry of Land and Resources and the State Administration of Surveying, Mapping and Geoinformation jointly issued the Overall Plan for the Construction of a Land Space Basic Information Platform. The plan proposes to build relevant standards and norms and data resource systems for basic information data of land and space[2]. With the formation of the Ministry of Natural Resources[1], the informatization of land resources and natural resources has a new connotation in the new situation. In November 2019, the Ministry of Natural Resources issued the Overall Plan for Informatization Construction of the Ministry of Natural Resources, which requires the establishment of a three-dimensional "one map" of natural resources to integrate and standardize various databases like land, geology, minerals, oceans, and surveying and mapping etc. According to the unified standards, a unified natural resource "one map" big data system of "above ground and underground, land and sea connection" is constructed[3]. This paper will discuss how to build and apply the natural resource data governance system under the new situation based on the practical case of the big data center of the land space basic information platform.

2. Status quo of data governance of natural resources

Assisting natural resource departments in performing the responsibilities of "two in one"[1] and refined management of natural resources are the key needs of natural resource informatization. At present, the data management system structure built in the period of land resources informatization is difficult to meet effectively, and there are mainly the following problems[4].

(1) Scattered storage, decentralized management, data storage media, format and standards of the land, surveying and mapping geographic information, geological environment, mineral resources and other data are not uniform. It is urgent to improve management and storage capabilities. Due to the establishment of the Ministry of Natural Resources, the management of planning, marine, forestry and grassland and other data are unified, and there is no unified data management system to adapt to it.

(2) The data included in the management of the natural resources department generally have problems such as missing fields, inconsistent coordinate systems, and inconsistent graphical attributes, and the current situation of various types of land, minerals, and surveying and mapping data is uneven, and some urgent data are difficult to obtain and update in time.

(3) There are significant differences between the data originally attributed to the forestry and grassland, marine and planning departments and the caliber and accuracy of the land and surveying and mapping geographic information data.

(4) Although the three major relationships of space, business and temporality are involved in the data, they lack a unified data model to organize, manage and maintain.

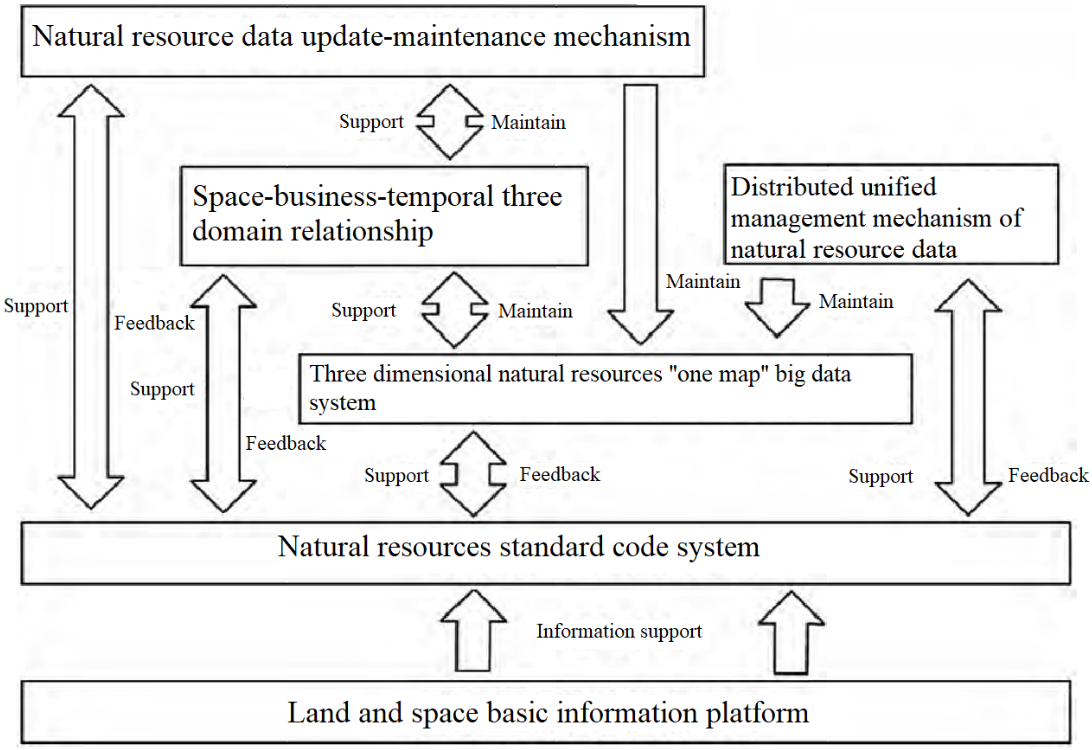

Figure 1. Relationship between the five parts of the natural resource data governance system and the basic information platform of territorial space.

3. Construction of natural resource data governance system

In order to solve the above problems, natural resources departments at all levels need to fully consider the "two in one" responsibilities and refined management needs of the Ministry of Natural Resources on the basis of the existing land resources data management system, integrate all kinds of natural resource data, adapt to local conditions, and build a natural resource data governance system.

The construction of a natural resource data governance system consists of five parts (**Figure 1**):

natural resource data standard specification system, three-dimensional natural resources "one map" big data resource system, space-business-temporal three-domain relationship, distributed unified management mechanism of natural resource data, natural resource data update-maintenance mechanism.

3.1 Establish a standard and normative system for natural resource data

In accordance with the requirements of the "two in one" responsibilities of the Central Ministry of Ecological Civilization Construction and Ministry of natural resources, sort out the original data standards for land, surveying and mapping, geology and mineral resources, oceans, forests and grasslands, water resources and land spatial planning, and incorporate them into the unified standard system. Standards that already exist should be absorbed and integrated as much as possible, and those that have not yet been established need to be re-established. Determine five major types of standards and specifications, such as data aggregation standards and specifications, data organization standards, data quality standards, data update standards, and data application and sharing standards, corresponding to all aspects of natural resource data governance.

3.2 Construct a big data resource system of "one map" of three-dimensional natural resources

Under the framework of the standard specification system, a big data resource system of "one map" of all-space three-dimensional natural resources that integrates "above ground and underground, land and sea connection" is constructed (**Figure 2**). Mainly the following work are carried out.

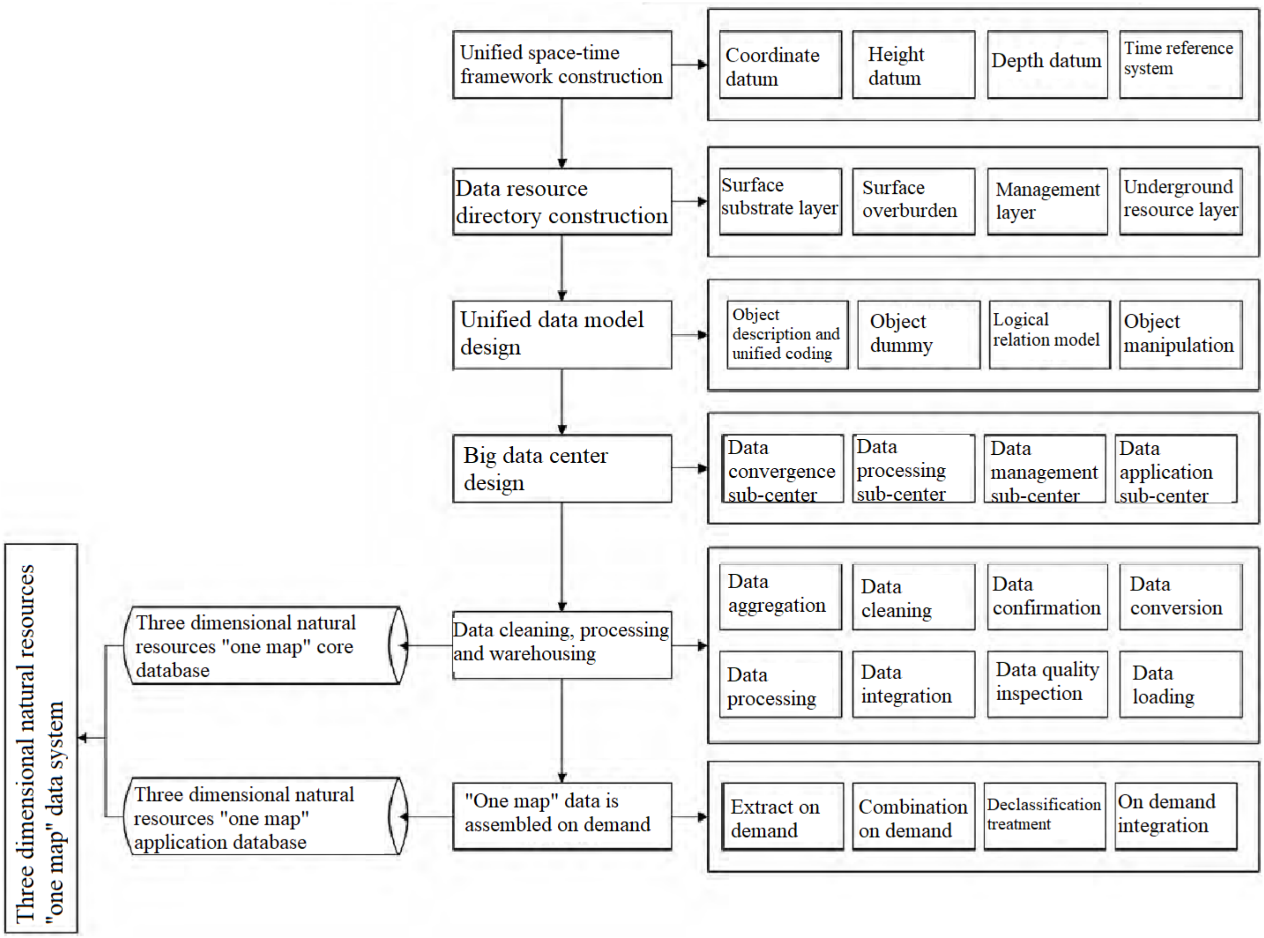

Figure 2. Construction of a big data resource system of "one map" of three-dimensional natural resources.

3.2.1 Unified data spatio-temporal framework construction

The 2000 national geodetic coordinate system, the 1985 national elevation datum, the time reference system, etc. are used.

3.2.2 Data resource directory construction

Follow the principles of scientific nature, practicality, scalability and uniformity, fully consider the existing natural resource data status of land, forests and grasslands, wetlands, oceans, geology and minerals, land spatial planning, etc., and construct a convenient data distribution organize and manage and share the data resource directory of the application.

3.2.3 Unified data model design

Using object-oriented theory and methods, following the principle of “data and application separation”, the spatial elements (objects) are designed as the spatial objects of the basic information of the national land space, including the object entity model and the relational logic model. Through unified object description and coding, conceptual model design, logical model design, and model manipulation rules, the three major relationships of space, business, and temporal state of objects are established, and a unified data model is constructed, and organically links with the business behavior of object status, planning, and natural resource management[2,4].

3.2.4 Big data center design and development

Big data center requires the ability to efficiently organize, store, and manage data resources organized based on a unified data model, supporting a variety of data formats including vectors, grids, attributes, time series, documents, videos etc. It is designed as a “physically dispersed, logically centralized” structure. Construct three-dimensional natural resources “one map” core database and application database as the carrier of each type of data under the data resource system. The relationship between the three major databases and big data center under the natural resources data governance system is shown in **Figure 3**.

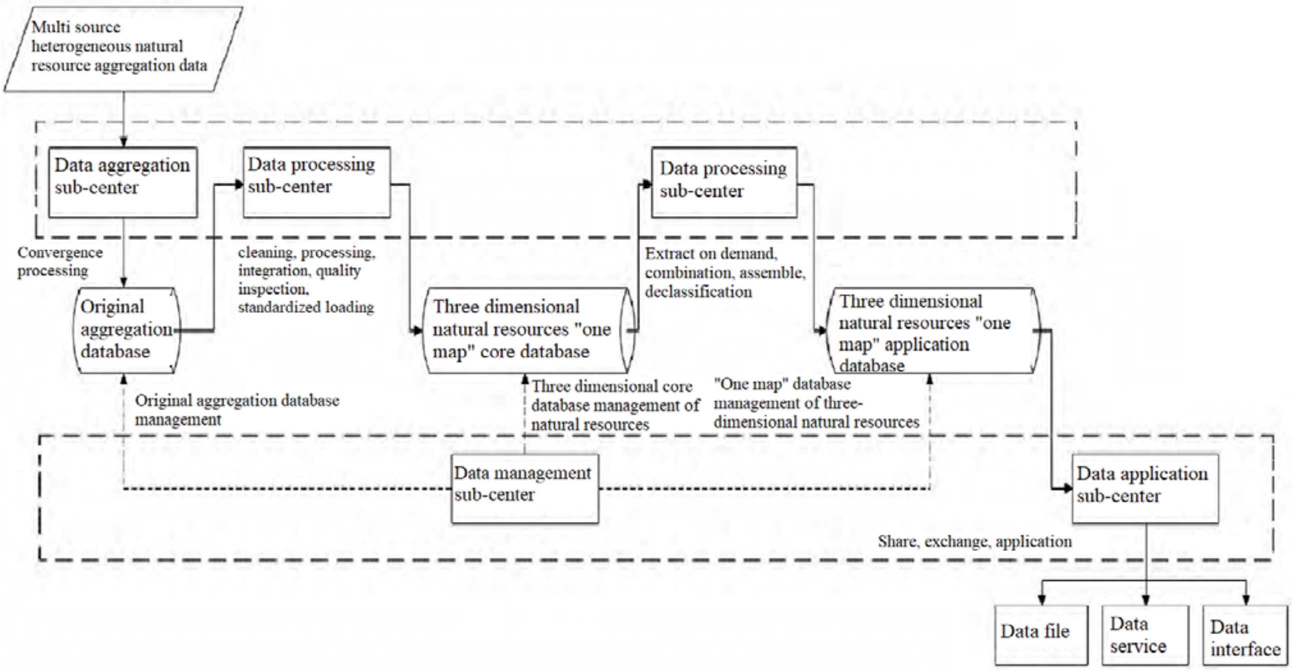

Figure 3. The relationship between the three major databases and big data center under the natural resources data governance system.

3.2.5 Data cleaning, processing and loading

(1) Digitize and spatialize the data. Digitize the paper archives, extract the information in the scanned file into the data model, and spatialize the spatial information that hasn’t been spatialized, such as changing the coordinate points or coordinate strings in the table into GIS data formats.

(2) Data is processed according to data quality standards and specifications, including topology processing, attribute processing, etc.

(3) Differential conflict detection and fusion processing of multiple versions of the same element

data: for example, multiple versions of basic farmland data are integrated and processed.

(4) Standardize the quality inspection of the integrated data according to the data quality standard specifications.

(5) For data resources that have not been established or have greatly changed the data structure of the established library, they shall be standardized and stored in accordance with the data organization specifications and unified data models. The data resources of the established database data structure that have not changed much need to be transformed in accordance with the new standards and included in the unified management of the core database of the “one map” of three-dimensional natural resources.

3.2.6 Assembly of application data on demand

After forming the core data of the “one map” of three-dimensional natural resources according to the above five steps, according to the sharing and application needs of the three major application systems of natural resources and other industry departments, the corresponding “one map” application data is derived after the on-demand combination, integration and declassification, which are included in the unified management of the three-dimensional natural resources “one map” application database.

3.3 Spatial, business, temporal three-domain relationship construction

After completing the construction of the natural resource data standard specification system and the resource system, it is necessary to further establish the multi-dimensional association between the data, discover and maintain the spatial, business and temporal relationships between the data, and find out the interaction of the three-domain relationship based on the entity. Solve the data linkage update problem base on the three-domain relationship, maintain the consistency of the data system as a whole, and lay the foundation for big data mining based on complete data and data relationships.

3.3.1 Sort out and maintain with spatial relationships as the main line

The implicit spatial relationship is discovered through the spatial position of the entity, and the corresponding tenses and properties of its spatial entities are derived from the spatial relationship. Like that by maintaining the relevant spatial relationship of the real estate rights entity, the land acquisition department can quickly determine the owner of the right to use the state-owned land, the owner of the above-ground building or structure, and the mortgage right or right restriction attached to the structure (administrative reconsideration or administrative litigation during court seizure, objection period), improving the efficiency and accuracy of the land acquisition department.

3.3.2 Sort out and maintain with the business relationship as the main line

By combing the administrative approval and supervision matters, the various data and related relationships involved in the whole chain of business handling are found and maintained. For example, the dynamic lengthening of the three lines of control in the land spatial planning, the relationship between the change of the boundary line and the implementation and supervision of the land spatial plan, the protection of cultivated land, the control of use, and the ecological restoration of the land space.

3.3.3 Sort out and maintain with temporal relationships as the main line

Taking the temporal relationship of managing data production and business processing time series and the evolution relationship of natural features of land space as the main line, the business objects and spatial objects are connected on the timeline to record their related spatial and attribute information.

First of all, using tense relationships can trace the causes and consequences of some administrative approval events. For example, the various approval links of engineering construction projects: project initiation, pre-examination and planning approval of land use, application for approval of agricultural conversion or land acquisition involving the occupation of agricultural land or collective land, land acquisition, land supply, completion of construction projects and check of planning, registration of real estate. Establish the temporal associations, so that the temporal relations can be used to inquire about the approval of the previous business when doing the latter business.

Second, restore the historical cross-section of natural resource entities to assist decision-making. For example, in the land acquisition, it is often happened that due to the urgency of the project, the construction unit will first carry out the earthwork filling and excavation in the case of not calculating the amount of earthwork. After the completion of the filling and excavation, the construction unit is difficult to liquidate the cost. At this time, if the natural surface of a certain point can be restored, find the surface situation of the filling party at the time before the excavation is carried out, and then liquidate the cost for the construction unit, thus solving the relevant problems effectively.

3.4 Construction of a distributed unified management mechanism for natural resource data

In order to solve the problem of data property rights, open up data channels within the natural resources department, better manage natural resource data, and achieve efficient and sufficient data sharing, exchange and application, the *Ministry of Natural Resources Informatization Overall Construction Plan* proposes to establish a distributed unified management mechanism for natural resource data. According to the actual situation of natural resource data affiliation units and data resources, three ways can be selected to build a distributed unified management mechanism for natural resource data, so as to realize the integrated and collaborative management of natural resource data resources with multiple sources and physical dispersion.

(1) Distributed data management based on the unified data resource directory. Each data resource is still stored on the distributed data sub-center node. The sub-center publishes the resource directory through the service, and the main center manages the resource through the resource directory instead of the data itself.

(2) Distributed centralized management. The data of each sub-center is regularly or irregularly transferred to the main center for unified management.

(3) Hybrid management. It is mainly managed in the form of data resource catalog, but it adopts the centralized data collection and management for specific data.

3.5 Natural resource data update-maintenance mechanism

In the construction of the standard normative system, the construction of the big data resource system, the combing and maintenance of the three-domain relationship, and the distributed centralized management of the natural resources data governance, it is necessary to further use the information platform to establish an update-maintenance mechanism for the three-dimensional natural resources "one map" big data system, and ensure that the three-dimensional natural resources "one map" big data system can maintain in real time, correct and consistent through the dynamic update, linkage update and error correction mechanism of data.

3.5.1 Establish a dynamic update mechanism for the "one map" big data system of three-dimensional natural resources

According to the situation of data aggregation, it is divided into daily natural resource business update, other industry departments sharing data aggregation update, Internet of Things sensor access data update, survey, surveying and mapping, geological survey project data exchange update, network capture data aggregation update, index update based on aggregate data, etc. Then determine the rules that trigger the update, and the time or version information configuration after the update etc.

At present, there are three main dynamic update modes for spatio-temporal databases[7] (**Table 1**).

(1) Regular update. Update the entire spatio-temporal data set as a whole according to a certain period of time.

(2) Degree update. Set a rate of change threshold. When the rate of change of the entire spatio-temporal dataset exceeds the threshold, it is up-

dated as a whole.

(3) Incremental update. After the spatio-temporal feature changes, the spatio-temporal feature is updated. Incremental updates can be further subdivided into incremental updates triggered by changes and incremental updates with cumulative changes in practice. Change-triggered incremental update refers to the incremental update that triggers the incremental update when the change occurs and is detected by the system, and the incremental update of the change accumulation refers to the incremental update of the elements of the change that occurs to a certain extent; or receive features first and detect if they have changed, and when a certain time period is reached, incrementally update the changed features.

Table 1. Dynamic updating mode of natural resource data from multiple sources

Data source	Dynamic update mode
Business system interface	Incremental update
Public service platform data interface	Periodic update, incremental update
Thematic data file	Periodic update
Sensor interface	Change triggered incremental update
Data documents of natural resources survey, surveying and mapping, geological survey and other projects	Periodic update, degree update
Network capture data	Incremental update
Public feedback data	Change accumulation incremental update

3.5.2 Establish a linkage update mechanism for the “one map” big data system of three-dimensional natural resources

(1) Linkage update based on the business relationship of spatio-temporal objects of natural resources.

Based on the business relationship between spatio-temporal objects of natural resources, the linkage update relationship between the semantically related elements of business is established. For example, parcels, boundary site lines, and boundary site points are inseparable, and the combination of boundary site points and boundary site lines constitutes parcels, and any one of the three changes will cause changes in the other two elements. The types of three linkage changes can be as many as 14[8].

(2) Multi-scale spatio-temporal data linkage update

Through the object unique identification code, we get the same name of the feature of different scales. The multi-scale linkage update relationship between the elements of the same name is established, and the general principle is that the large scale element change linkage updates the small scale data.

(3) Vertical data linkage update at the administrative level

Due to the needs of administrative management, the relevant data of the lower-level department caused by the issuance of data by the superior department is updated. Or the lower-level department reports and transfers the data in accordance with the requirements of the superior, and then the linkage is updated to the database of the superior department after the quality inspection and review of the superior department.

(4) Linkage update based on data genealogy relationship

The derivative objects used for various thematic applications of natural resources are generated by the extraction, processing and fusion of three-dimensional natural resource “one map” data objects. In natural resource data governance, a data spectrum relationship needs to be established, clarify the source data and target data of data flow and evolution, and the change of source data in the spectrum triggers the linkage update of target data.

3.5.3 Establish a fault correction mechanism for the “one map” big data system of three-dimensional natural resources

In practice, there are some data semantic conflicts that cannot be detected through the regular quality inspection process, such as the misalignment of decimal points or type errors in some spatiotemporal feature attributes. In the data verification link, since there are more sources of objects with the same name, through the cross-comparison of objects with the same name, such conflicts can be found, and the data administrator determines whether it is indeed an error.

The system continuously accumulates the verification rules by establishing a data verification rule base. As long as the objects with the same name with multiple sources with the same name are gathered into the database, the listening mechanism can be enabled to confirm the correctness of the objects with the same name.

4. Data analysis and mining based on natural resource data governance

The premise of data analysis and mining is the existence of a large amount of digital information, that is, the need for a complete database as the basis, which is fully met in the current degree of informatization of natural resources[6]. After the basic completion of data governance for natural resources, the competent departments for natural resources may further excavate and analyze the inherent, implicit, and non-explicit relationships and operating mechanisms between various entities of natural resources on the basis of data resources, and assist in intelligent supervision and decision-making of natural resources.

First of all, through big data analysis technology, the basic spatial analysis of traditional data management or a variety of big data obtained through aggregation and exchange is carried out, that is, to solve the problem that traditional analysis algorithms cannot quickly analyze and calculate in the big data environment. For example, the OD matrix of mobile phone information data is used to analyze the travel characteristics of urban residents. The mobile phone user base is large, the sampling rate of mobile phone signaling is high, and the time resolution can reach the second level, so the amount of data is huge[10,11]. In the case of Beijing Mobile, for example, there are more than 18 million samples in the Beijing area, generating 1 billion pieces of mobile phone signaling data every day[12]. Traditional data analysis technology cannot process such a large amount of data information and effectively simulate the flow of people. Spatial analysis itself takes a long time. If we analyze the refined data, a prefecture-level city often has tens of millions or even hundreds of millions of different layers of patches. A variety of spatial analysis processes needed to be carried out in a short period of time, and big data is needed for efficient analysis and mining.

Second, big data must be combined with data mining, not just for information extraction, especially for mining implicit, non-obvious patterns, laws, and knowledge[5]. Through big data mining algorithms, find the implicit relationship and value of data. For example, on the basis of real-time perception of natural resources, a predictive model is fitted based on a large amount of data, and the future development trend of the indicator is inferred. Relevant models such as cellular automata are used to predict urban development space based on natural resources and urban correlation data test[13-15].

5. Informatization practice of data governance of natural resources

In the *Overall Plan for Informatization Construction of the Ministry of Natural Resources*, the big data system of “one map” of three-dimensional natural resources is defined as “the basis for ‘speaking with data’”. The land space basic information platform is the hub of data aggregation, data fusion, data management, data application and sharing in the “one map” big data system of three-dimensional natural resources. It can be said that without the support of the information system of the land space basic information platform, it will be difficult to build and operate the natural resource data governance system in the new era. The functional framework of the big data center of the land space basic information platform is shown in **Figure 4**.

In the informatization practice of natural resource data governance, in accordance with the construction requirements of the central ecological civilization construction and the “two in one” responsibility positioning of natural resource departments, and the practical experience accumulated in various places, the design idea of the natural resource data middle platform is adopted, and the basic information platform for land space (V1.0) big data center is designed and developed, which undertakes the task of supporting and assisting the data governance of natural resources.

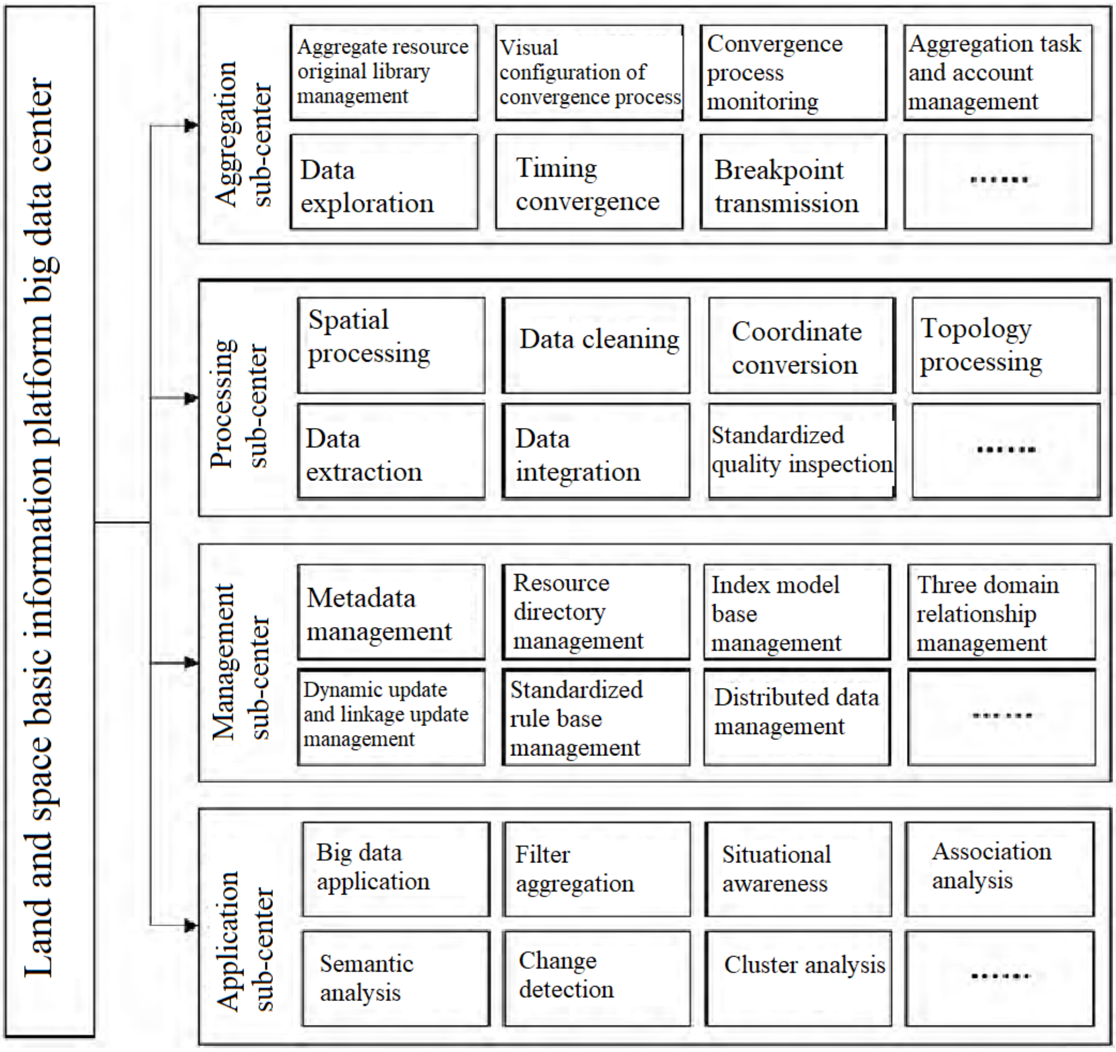

Figure 4. Functional framework of the big data center of the land space basic information platform.

The big data center is divided into four key modules: aggregation sub-center, processing sub-center, management sub-center and application sub-center, which realize the information support for all aspects of natural resource data governance from data aggregation, processing and integration, organizational storage management to shared applications, and realize and maintain the standard normative system of data governance through the information system platform, the big data resource system, the three-domain relationship, the distributed centralized management and update and maintenance mechanism. Provide a solid data foundation for the preparation and implementation supervision of land spatial planning and the supervision and decision-making of natural resources supervision of natural resources departments at all levels, and truly improve the refinement and scientific level of natural resources and land space management.

6. Conclusion

The natural resources data governance system is not a reversal of the existing land resources data management system, but a system standing at a new height of natural resource informatization to absorb, lift, and perfect the original system under the new requirements of the national ecological civilization construction, the “two in one” responsibilities of the natural resources department, and the refined management of natural resources. The competent administrative departments for natural resources at all levels need to use a more mature and advanced information system platform to achieve full coverage, multi-angle, and multi-level in-depth governance of various natural resource data, pushing informatization of natural resources to develop to a higher level, and truly realized "speaking with data, managing with data, making decisions with data, and innovating with data".

Conflict of interest

The authors declared no conflict of interest.

References

1. Central Committee of the Communist Party of China. Shenhua dang he guojia jigou gaige fangan (Chinese) [Deepening the reform program of party and state institutions] [Internet]. Available from: http://www.gov.cn/zhengce/2018-03/21/content_5276191.htm#1.
2. Ministry of Land and Resources, National Administration of Surveying, Mapping and Geoinformation. Guotu kongjian jichu xinxi pingtai jianshe zongti fangan (Chinese) [Overall plan for the construction of a land and space basic information platform] [Internet]. Available from: http://www.cac.gov.cn/wxb_pdf/20170817001.pdf.
3. Ministry of Natural Resources. Ziran ziyuanbu xinxihua jianshe zongti fangan (Chinese) [Overall plan for informatization construction of the Ministry of Natural Resources] [Internet]. Available from: http://www.gov.cn/xinwen/2019-11/23/5454833/files/29f2c1b9186a4d798d677dfc2bc8021d.pdf.
4. Yang H, Lin L, Zhong Y, *et al*. Key technology research and application of land resource big data integration and update. Geospatial Information 2019; 17(6): 29–32.
5. Li Q, Li D. Big data GIS. Geomatics and Information Science of Wuhan University 2014; 39(6): 641–644.
6. Guo R. IT applications in land resources management: From content management to knowledge management. Engineering Sciences 2009; 11(10): 67–71.
7. Zhou X. Incremental updating of cadastral database. Beijing: Surveying and Mapping Press; 2007. p. 10–11.
8. Cao Y. Study the Methods of Incremental Linkage Updating Spatial Database [MSc thesis]. Hangzhou: Zhejiang University; 2014.
9. Tian W. Geospatial information change detection and update based on volunteered geospatial information [PhD thesis]. Wuhan: Wuhan University; 2013.
10. Wang Y. Research on urban spatial vitality characteristic evaluation and internal mechanism of shanghai central city based on mobile phone signaling data [MSc thesis]. Nanjing: Southeast University; 2017.
11. Cai Z. Analysis and modeling of urban mobility based on big data [PhD thesis]. Hangzhou: Zhejiang University; 2018.
12. Sun Z, Liu J, Yan N. Prediction of urban residents' OD matrix based on mobile phone big data. Mathematics in Practice and Theory 2019; 49(11): 68–76.
13. Xu Z. Study on the delimitation of urban growth boundary based on ecological background—Taking Xiamen City as an example [MSc thesis]. Hangzhou: Zhejiang University; 2019.
14. Yang Q, Li X. Calibrating urban cellular automata using genetic algorithms. Geographical Research 2007; 26(2): 229–237.
15. Li X, Yang Q, Liu X. Jiyu CA de chengshi yanbian de zhishi wajue ji guihua qingjing moni (Chinese) [Knowledge mining and planning scenario simulation of urban evolution based on CA]. Science in China (Series D: Earth Sciences) 2007; 37(9): 1242–1251.