Design and Implementation of Quality Inspection System for Image on National Platform for Geospatial Information Services in China

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Keywords: Quality Inspection, System Design, Image tiles data.

Abstract

This article is based on the data update characteristics of the online service for National Platform for Geospatial Information Services (TIANDITU) imagery data, and it designs and implements a full-process imagery data quality inspection system specifically for imagery tile data. The development and application of this system have made the quality inspection and update process of TIANDITU imagery data more scientific and efficient, significantly enhancing the efficiency of the quality inspection and update process for TIANDITU imagery data. The article provides a detailed introduction to the system's architecture, design, implementation, characteristics and application. It also proposes optimizations to be made in algorithm optimization, user interface, and system stability. This article provides new ideas for quality inspection and publishing based on image tile data.

1. Introduction

With the increasing importance of spatial data, web-based geographic information services play a significant role in the field of public service. The National Platform for Geospatial Information Services in China, known as "TIANDITU," has secured a prominent position in public service, particularly in sharing and distributing information resources across the country. Since its establishment in 2001, the national platform has accumulated vast and large-scale data.

As China's authoritative geographic information service platform, National Platform for Geospatial Information Services (TIANDITU) owns rich types and massive data resources. Among the map services it provides, image map service has the largest number of visits and largest demand. Thus, only accurate and rapid updates can meet the needs of different users on platform.

Image data update of National Platform for Geospatial Information Services has achieved linkage update between national node and sub nodes (32 provincial level nodes). Typically, provincial nodes are responsible for data production and data self-inspection. National node, however, is responsible for image data quality inspection and data release. In the face of massive data on national node, quality inspection should put a lot of efforts and effects the significant role in the whole linkage update.

This paper proposes that the system architecture , key technologies and implementation of the quality inspection system for image. Also, the application of the system for the actual production image is introduced. As the amount of data and speed of data released continues to increase, the automation of quality inspection will be discussed in this paper.

2. Related Works

At present, there are many mature quality inspection methods at home and abroad for satellite images and aerial images, and many quality inspection models that can be directly applied in practice in certain research. However, the direction of its use and user objects are not align with TIANDITU. They are predominantly utilized in national initiatives or local area research.

In order to reduce the time of data exchange with provincial nodes and speed up the release, the image data received and inspected by the national platform are all tiles data (the amount of data in the same area is about one-fourth of traditional remote sensing image data), and the tile data is in the platform's own format and coding. So in view of the special forms of data integration and application patterns, the model that the national platform can learn from may come from the internet maps, such as Bing or Google, etc. But it is impossible to explore the deeper data quality control methods behind it.

Since the beginning of platform construction, it has been committed to improving the efficiency of image release and quality inspection, and has developed some software tools that are very meaningful at the time. However, because different tools solve different problems in different aspects of image data inspection, image data quality inspection release has always lacked a process quality inspection system.

Tile data is usually generated from remote sensing image data through a series of processing steps. It is designed to facilitate network transmission and reduce hardware requirements for image processing. Each tile is a complete entity that can be independently requested and used by users. Each tile data contains latitude and longitude information, and the latitude and longitude position of the tile data can be calculated through its level, row number, and column number. The TIANDITU tile database is divided into 18 levels and covers the entire globe.The image data submitted by the provincial nodes of TIANDITU is in the form of image tile data. Therefore, this system focuses on various aspects involved in the quality inspection of tile data.At the beginning of the construction of Tianditu, in order to solve the problems of automation and inefficiency in quality inspection of image data, various quality inspection software were developed, such as metadata quality inspection software, tile quality inspection software, and tile data quality inspection platform. However, these individual quality inspection software could not work systematically. Operators needed to open different software multiple times for the same batch of image data quality inspection tasks, and even might need to copy one set of data to multiple machines, resulting in low efficiency of quality inspection.

The research of this paper solves the problems of slow and non-process quality inspection of tiles image data. It plays a historic and critical role in improving the quality inspection and release efficiency of image data on the platform. Figure 1 shows operation screen for quality inspection personnel in the image quality inspection system.

Figure 1. Image quality inspection system .

3. System Architecture

The architectural design of quality inspection system is part of the overall architectural design of TIANDITU and it runs under the whole cloud architecture. So the quality inspection system architecture design shows that it is comprised of four levels, which are Cloud services level, data level, system level and user system level (Figure 2).

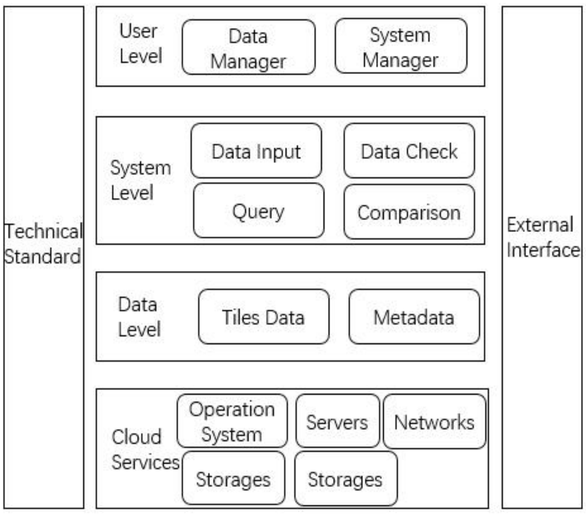

Figure 2. Quality inspection system architecture

4. System Design and Implementation

4.1 System function design

The key point of quality inspection of platform image tile data is to automate and process quality inspection projects, combine manual and automation, and complete the quality inspection of all data. Therefore, the system fully considers the quality inspection items (image data accuracy, map clarity, color, metadata, cloud coverage, etc.) and manual quality inspection operation process, and designs the corresponding functional modules of the system. Figure 3 shows the function module of quality inspection system.

4.1.1 Image tiles data preprocessing

In the process of image tiles data preprocessing, the provincial node would prepare the submitted data for service publication for each batch submission, and submit the service address and metadata to the system(i.e. the national node). The national node integrates the image data service, and the metadata is checked (automated), and the valid map service and correct batch of metadata can be checked in the next stop.

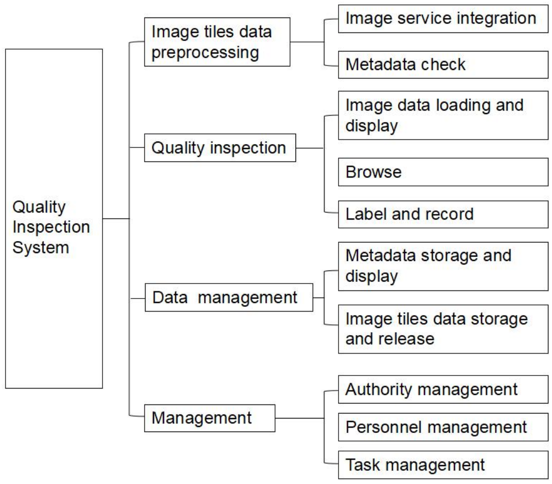

Figure 3. Function module of quality inspection system

4.1.2 Quality inspection

The image quality inspection is the core part of system. Based on integrated image data services, data quality inspection personnel can load map services and metadata during quality inspection, mark data problems, and export data quality reports based on the masks. On the quality inspection page of system, quality inspection personnel can also load with the online service of the TIANDITU, compare the quality of the data map, and also load grids of different densities to allocate densities to allocate and control their own inspection areas. Figure 4 shows the inspection page of quality inspection system. The two parts are online maps and maps submitted by provincial nodes. The quality inspector could mark it on the map. Marking areas can be done using points or surfaces, and the type of error for the marked points or surfaces can be selected. Quality inspectors can also provide detailed descriptions of the errors for provincial-level nodes to make modifications.

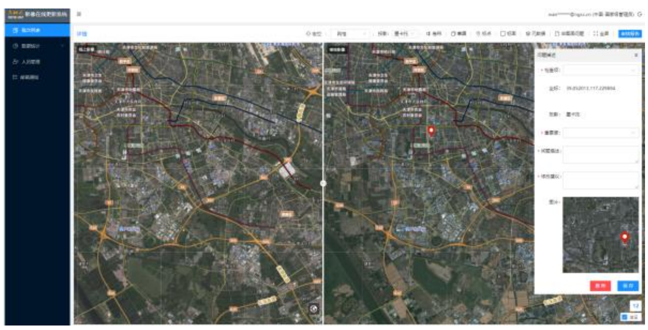

Figure 4. Inspection page of quality inspection system.

The inclusion of all quality inspection items into the system is it core function, directly influencing the quality of the platform’s image data services. Based on the characteristics of online image data services, the platform’s quality inspection primarily encompasses the following items, as detailed in Table 1.It is worth noting that in the table below, except for map quality , the system has implemented automation to minimize manual intervention and ensure the accuracy of quality inspection.The inspection of map quality involves quality inspectors making judgments on the quality of image data based on their own experience.This is a problem that is difficult to automate.

Inspection items	Inspection content
Image tiles data	Data integrity (no redundancy or loss), consistent with metadata, correct data format
Data accuracy	Alignment with platform vector data
Metadata	Correct Information (including temporal information, satellite type, resolution, producing unit, etc.)
Mathematical foundation	Correct coordinate system and projection
Map quality	Clarity, cloud cover, snow cover, noise and moire patterns
Management information	Data volume, data production unit and personnel

Table 1 Inspection content for platform

4.1.3 Data management

Metadata is stored and managed according to batches provided by provincial nodes, and can be displayed according to different information in the metadata (coverage, satellite type, time information, etc.). Image tiles data is also stored, managed and released in batches provided by provincial nodes.

4.1.4 Management

According to the operation characteristics of national node image data, more than 50 batches (about 4 million square kilometers) of data need to be processed in another month during the peak period. The image inspection system gives different rights to different personnel to support the task division, progress monitoring and personnel management of image data processing.

4.2 System implementation

The quality inspection system works on multiple nodes of the Internet. According to the characteristics of workflow in each stage, Web data service and B/S mode are adopted comprehensively, and the functions of core module are realized based on postgresSQL. Also, image tiles data is organized and managed via Object Storage Service (OBS). The programming language is Java and JavaScript.
Web data service is used to integrate the image data service of the provincial node data, and the metadata is automatically sorted out. The integrated data service is used by the quality control module to load images. Using the loaded image data service for quality inspection can reduce the time of data transmission, improve the efficiency of preprocessing, and shorten the time of data interaction.

4.2.1 Quality inspection implementation

Utilizing the B/S architecture, the system integrates a human-machine interactive quality inspection functionality within its quality inspection module, empowering users to effortlessly generate inspection reports online. JavaScript libraries offer web developers unparalleled flexibility, allowing them to tailor their approach to suit their specific needs and preferences, thereby enhancing the overall user experience and system efficiency.
When the inspection personnel access the inspection screen, the system automatically identifies and loads the map of the designated area for inspection. Given the extensive image data to be inspected, quality inspector can load a grid through the system and evenly allocate their own quality inspection areas based on this grid. For instance, one location per grid is selected for inspection. Different grids within the same area can also be assigned to different quality inspectors, with each inspector being responsible for their respective grid during quality inspections. Figure 5 illustrates a 25-kilometer grid system for the area under quality inspection. This grid enables quality inspectors to select specific regions for inspection, ensuring a comprehensive and thorough approach to quality assurance.

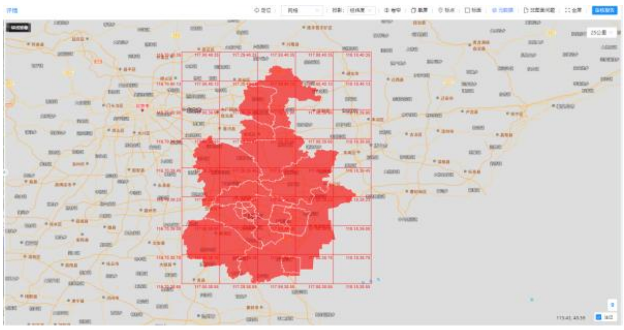

Figure 5. 25-kilometer grid system for the area under quality inspection

During interactive operations on the page, the system facilitates precise map positioning using latitude, longitude, and zoom levels. It also enables seamless projection switching and dynamic screen display transformations, including the capabilities to toggle between split-screen, dual-screen, and full-screen views. Additionally, the system allows for the annotation of problematic points and areas, streamlining the process of identifying issues and generating problem reports.
After the automation quality inspection tool initially screens and marks potential problematic data, quality inspectors need to manually select and confirm these annotated points based on their professional judgement.
Utilizing template engines and database technologies, the system automates the extraction of quality inspection results and the generation of reports. Based on pre-defined template formats, the system automatically populates the collected data and records from the quality inspection process, resulting in standardized PDF files. This process significantly enhances the efficiency and accuracy of report production, while minimizing human errors.

4.2.2 Data storage and management implement

The data involved in the system primarily encompasses the management, presentation ,and storage of metadata and image tiles data. In this module, the database core is grounded in PostgreSQL for managing the metadata associated with submitted imagery, while the Object Storage Service (OBS) is utilized for the structured organization and management of image tiles. The backend development leverages Java as the programming language, and the frontend employs JavaScript, fostering a seamless integration that ensures the efficient processing and presentation of data. Object storage is a distributed data storage method that stores data in objects as the basic unit. Each object has a unique identifier (Object ID) and metadata (Metadata). It has powerful scalability, reliability, supports high concurrent access, and fast read-write operations. Therefore, object storage is a very suitable method for Tianditu to manage its data.
In accordance with the national level requirements for data organization and distribution, OBS is divided into 32 regions. Each provincial node has its own dedicated data transmission area and path, and they are unable to access each other's systems. This arrangement not only ensures the security of data but also guarantees the rationality of data organization.

Figure 6 illustrates OBS data storage and partitioning. Different provincial nodes cannot access or modify data from other regions, ensuring data security and the rationality of data storage.

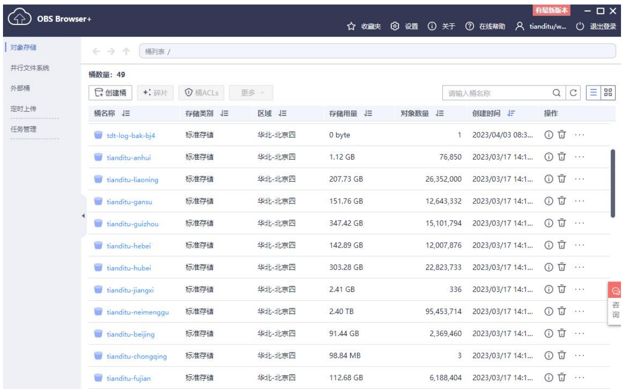

Figure 6. OBS data storage and partitioning.

5. System characteristics and application

5.1 System characteristics

5.1.1 Comprehensive Quality Inspection Content :

The new image quality inspection system, through its highly integrated design, achieves seamless integration of all critical quality inspection items, creating a unified and comprehensive quality inspection platform. This transformation not only ensures the integrity of the quality inspection process, covering all necessary inspection dimensions, but also greatly simplifies the operational procedures for quality inspectors. Within this single system, quality inspectors can easily access and process all relevant image data without the need for frequent interface or software switching, thereby effectively reducing operational complexity and minimizing the risk of human errors.

5.1.2 Easily System Scalability:

The system not only solidly supports the current core business processes but also reserves abundant interfaces and frameworks to support the expansion of future business processes and the upgrading of functional modules. This design enables the system to seamlessly integrate with every iteration of imagery data updates, whether it be fine-tuning of data processing workflows or the introduction of entirely new features, all of which can be rapidly and effectively implemented within the system.
Of particular note are the system’s built-in functional modules for data display, statistical analysis, and export of statistical results, which serve as important pillars for future expansion (Figure 7). Additionally, the system's display function provides various possibilities for conditional filtering. Users can filter and display results based on submission time, release time, satellite type, time information, etc. All displayed results can be exported in a tabular format for guiding the update of TIDITU imagery data. Figure 8 shows the current data status under different filtering conditions.

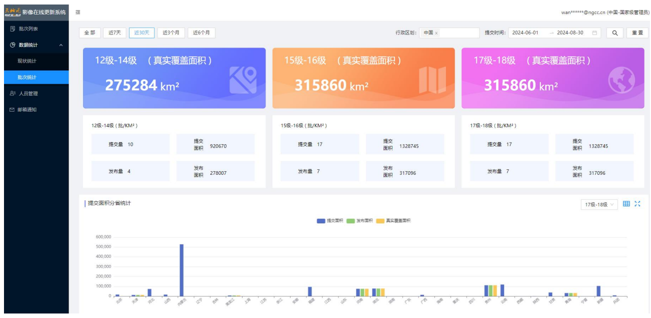

Figure 7. Data display module

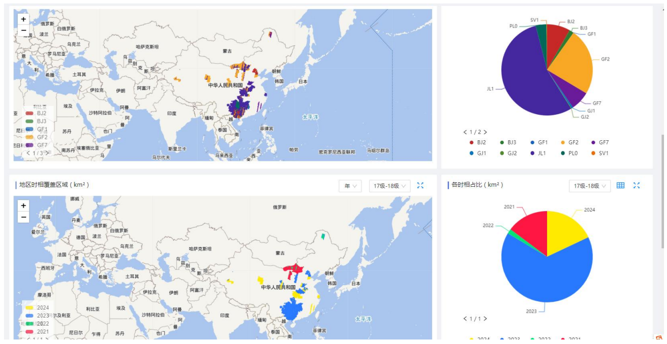

Figure 8. Current data status under different filtering conditions.

5.1.3 High level of automation :

The high degree of automation of the system greatly simplifies the operation for quality inspectors. The automated processing of functions such as metadata quality inspection, map loading, quality inspection report generation, and data display calculation significantly reduces manual operations and enhances the accuracy of quality inspection. The quality inspection personnel of national nodes can also load the current online image services to compare the data quality of the same location, such as accuracy and color.
he system also provides a pre-inspection function, which is one of its major automation features. When provincial nodes submit data, the system performs pre-inspection on the metadata being uploaded. Metadata with quality issues cannot be submitted and will receive error prompts. After modifications, the provincial nodes can resubmit, and if the system's pre-inspection finds no issues, the submission can proceed smoothly. This function saves time in data interaction that would otherwise be caused by unqualified metadata.
For users of provincial nodes, the system automatically sends emails to notify them of the successful submission of data, the status of the data (pending review, under review), and the results of the data review. This ensures a swift and efficient flow of data outcomes from submission to publication.

5.1.3 Authorization management security:

The update of image data at the national node involves multiple links and diverse user roles. Roles such as national level administrators, national quality inspectors, and provincial node data managers require different levels of authority, ensuring the smooth progression of data quality inspection and updates while safeguarding data security. National administrators hold the highest level of authority, enabling them to allocate tasks, view and modify the status of any batch of data, participate in data quality inspection, and view the data display on the national platform. Furthermore, they can add and delete other role members of the platform (such as data quality inspectors, provincial node data administrators, and provincial node data officers) while granting appropriate permissions to these roles. Additionally, national administrators have access to databases of all systems (Figure 9). Data quality inspectors are solely responsible for conducting quality inspections on the platform’s data. They review the “pending quality inspection”data on the platform, and upon completion of the inspection, the “qualified” or “unqualified” data is transferred to the next process.

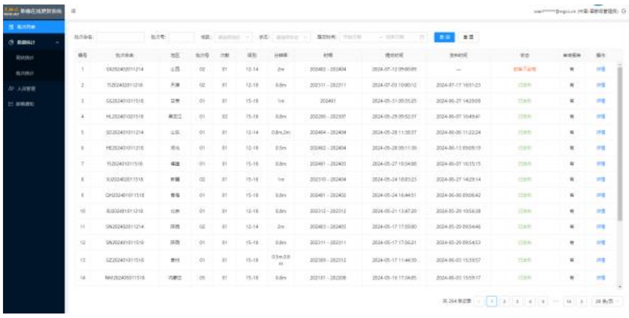

Figure 9. Data management list for national administrators

5.2 Application

In 2021, this system was officially introduced for the updating of image data, with all 32 provincial nodes seamlessly collaborating with the national node to achieve synchronized updates of image data. By 2024, the system had been continuously updated and utilized, facilitating the completion of approximately 260 data update batches and the inspection of approximately 18 million square kilometers of data. This comprehensive application has significantly enhanced the speed and efficiency of image data quality inspection and publication. Provincial data administrators are responsible for uploading data into the system, reviewing the results of data quality inspections and making modifications to the data as needed. They have access to view all the data submissions made within their province but cannot view or access data and databases from other provinces.
The use of the quality inspection system has greatly shortened the time from data submission to online availability, significantly improving the efficiency of image data updates. Simultaneously, it has also contributed to enhancing the online service quality of TIANDITU, resulting in a significant increase in data richness and overall improvement in user experience.On the other hand, rapid quality inspection updates also enable national nodes to process and publish more image data, fully activating the image data of provincial nodes. Each provincial node can submit multiple batches of data at any time each year, ensuring the freshness of the online service data of TIANDITU images and accumulation more historical image data. Figure 10 shows that as the publishing speed increase, multi-temporal data is also continulously enriched. Figure 11 shows the online service for TIANDITU’s image data.

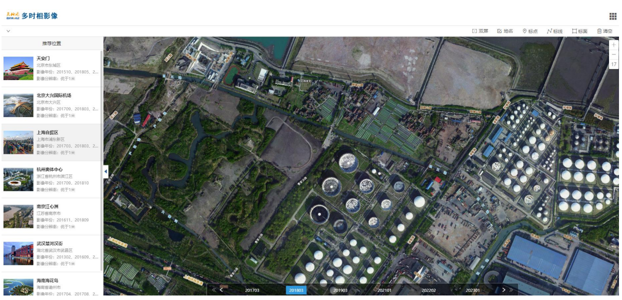

Figure 10. multi-temporal data on TIANDITU

Figure 11. Online service for TIANDITU’s image data.

6. Results

The current image quality inspection system embodies an advanced and cutting-edge architecture that is not only inherently reliable but also effortlessly scalable, catering to the evolving demands of the industry. This sophisticated system has been rigorously tested and proven to deliver unparalleled accuracy and remarkable stability, revolutionizing the way in which map quality inspection is conducted. By significantly enhancing the efficiency of the inspection process, it ensures that maps are of the highest caliber, meeting the stringent standards required by modern mapping businesses.
With the deep application of the system, some deficiencies have also been exposed. In the next step, the system will be optimized in several aspects such as algorithm optimization, user interface, and system stability. In terms of system algorithms, we will continue to optimize image processing algorithms and machine learning models to improve the accuracy and efficiency of quality inspection, and explore more dimensions of quality inspection indicators, such as ground object recognition, to gradually automate quality inspection items that are limited by the experience of image quality inspectors. In terms of the user interface, we will improve usability and aesthetics to enhance user experience. In terms of system stability, we will strengthen the system's fault tolerance mechanism and fault recovery capabilities to ensure stable operation under high concurrency and abnormal conditions.
As the map industry continues to expand and diversify, driven by technological advancements and increasing user expectations, the image quality inspection system remains poised for continuous improvement. Its adaptability and forward-thinking design ensure that it will seamlessly integrated with emerging technologies, future bolstering its capabilities and impact within the realm of image map services. In essence, this system serves as a cornerstone for ensuring the quality and reliability of maps, empowering mapping businesses to deliver exceptional products and services that meet the demands of a rapidly evolving market.

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