Techniques and methods of product quality inspection Urban Spatial Monitoring

Wenjuan Mao [1], Haitao Zhao [1, *], Bingquan Yao [1], Jin Zhou [1], Hongjing Tu [1]

[1] National Quality Inspection and Testing Center for Surveying and Mapping Products, Beijing, China - 67516521@qq.com

Commission III, ICWG III/IVb

Keywords: Urban Spatial Monitoring (USM), USM data, Quality inspection.

Abstract

Urban Spatial Monitoring (USM) data is a new form of fundamental geographic information product that captures and records the dynamic changes of urban land use and built environments. As an important component of the natural resources survey and monitoring system, USM provides strong support for the construction of the China Spatial Planning Observation Network (CSPON), a national framework for monitoring and managing spatial development across China. The quality of USM data results is related to the accuracy of statistical analysis outcomes, the scientific decision-making for national economy, people's livelihood and social development, as well as the reliability of natural resources management applications. However, ensuring the quality of such large-scale, multi-source spatial data remains a significant challenge. Based on the analysis of the characteristics of USM results, this paper proposes a three-tier inspection process including overall preliminary inspection, detailed inspection, and off-sample general inspection—each targeting different aspects of data quality; analyzes inspection parameters and items, and determines the inspection methods for different items; further identifies quality elements that can be automatically inspected by programs, and realizes batch automatic inspection of some items by establishing a rule base, while other quality items are evaluated through semi-automated human–computer interactive inspection, with common problems systematically identified and addressed. Finally, the quality inspection results of urban space monitoring data products covering 170 prefecture-level city survey areas spanning approximately 6 million square kilometers demonstrate that the technical route proposed in this paper is feasible, the quality evaluation results are objective, and the proposed approach can serve as a practical reference for quality assurance of large-scale geographic data products.

1. Introduction

1.1 Urban Spatial Monitoring

Urban Spatial Monitoring (USM) takes the land change survey data of the previous year as the monitoring background data, refers to the urban elements in the geographical national conditions monitoring results and various collected thematic data, and comprehensively adopts technologies such as remote sensing, artificial intelligence and big data analysis. Based on the remote sensing image data of the current year, through means including image comparison, indoor interpretation, field investigation and verification, and comprehensive analysis of spatial data, it completes the refinement and supplementation of urban spatial information by means of land use refinement, change scope labeling, and element extraction, and summarizes to form the urban spatial information dataset of the current year. USM can effectively grasp the total urban construction volume, land use structure, infrastructure, service functions and other conditions, providing data support for territorial space governance work such as territorial space planning formulation, urban physical examination and evaluation, and land use control.

1.2 Quality Requirements for Monitoring data

With the development of the USM project, result quality inspection is an important part of USM work. How to ensure quality, obtain authoritative, objective and accurate urban spatial monitoring information, conduct in-depth research on monitoring data quality inspection methods, and explore scientific and efficient quality control and inspection models are of great significance for the smooth completion of the project. Compared with basic surveying and mapping data results, urban spatial monitoring data results differ in content and quality requirements: (1) In terms of content, USM data breaks through the limitations of the seven traditional topographic map elements, enriches and expands as needed, and integrates other information such as economic, social and humanistic data. (2) In terms of quality requirements, basic surveying and mapping results are standardized products formed mainly through standardized surveying and mapping production processes, with their accuracy, content and data format strictly complying with relevant national standards; as a new form of geographic information product, monitoring data has obvious differences from traditional basic geographic information products in production technology and result organization form, and existing national standards and specifications are not fully applicable to the inspection and acceptance of this type of result.

By analyzing the differences between monitoring data and basic surveying and mapping data results, this paper proposes a set of processes and methods suitable for the quality inspection of urban spatial monitoring data results based on practical inspection work.

2. Quality Inspection Content and Method

In accordance with GB/T 18316-2018 and the "2025 Urban Spatial Monitoring Results Quality Inspection and Acceptance Implementation Plan", the quality inspection of urban spatial monitoring data results mainly includes 23 inspection items covering 8 inspection parameters, such as the completeness and storage validity of submitted results, mathematical foundation of results, format consistency, dataset consistency, scope completeness, attribute structure standardization, graphic

*Haitao Zhao, National Quality Inspection and Testing Center for Surveying and Mapping Products, Beijing, China - gismwj@qq.com

standardization, and error/missing rate. The specific inspection content and methods are shown in Table 1.

Tab.1 Contents and Test Methods of the USM data Quality Inspection

Test Parameters	Object to test	Test item	Test method
The integrity of the results and the validity of the storage	Document accessibility	Consistency with design requirements	Check and analyze comparative analysis
	Document integrity		
	Consistency of remittance requirements		
Mathematical basis of the result	coordinated system	Consistency with design requirements	Check and analyze
	Elevation Base		
	Projection Parameters		
Format consistency	guide cards	Consistency with design requirements	internal check
	file designation		
	file designation		
Data set consistency	Tolerance parameter	Consistency with design requirements	internal check
	DSD		
Range integrity	coverage area	Consistency with design requirements	Reference data comparison
	No elements are outside the scope		
Attribute Structure Specification	Attribute field naming	Consistency with design requirements	Check and analyze
	Attribute field type		
	Attribute field length		
Graphic Standardization	parameter curve	Consistency with design requirements	internal check
	Geometric Adhesion		
	An element with properties but no graphics		
	Extremely short, extremely small		
	The number of element nodes is less than 500,000		
Error rate	Accuracy of collection	Assess the integrity and accuracy of monitoring data	Reference data comparison Statistical analysis and comparison Field measurement
	Element integrity		

2.1 Reference Data Comparison Method

It is compared with various reference data such as land change survey data, field survey and verification data, as well as thematic data used in the production process (including education, medical care, social welfare, cultural and sports activities, landscape architecture, construction, water conservancy, and transportation) to determine whether the inspected data has errors or omissions, or to obtain the difference between the inspected data and the reference data. (1) Superposition inspection with image data: adopt manual comparison, superimpose with digital orthophoto maps, and check whether the plane position offset of elements such as roads, high-water boundaries of water systems, and buildings meets the technical design requirements; (2) Inspection against field survey and verification results: adopt human-computer interaction to check whether the attributes of urban spatial monitoring (USM) element data are consistent with field survey and verification data; (3) Inspection against professional data. The comparison and inspection of attribute values with thematic data can be automated by designing program modules. This automated inspection method based on computer program modules is characterized by high efficiency and accuracy, and it is recommended to use relevant programs for control and inspection in specific quality control.

2.2 Internal Inspection Method

The Internal Inspection Method refers to checking the inherent characteristics of the inspected data. This method inspects vector data through indoor means, such as checking the mathematical foundation of results, format consistency, standardization of attribute structure, and logical inspection between element layers.

2.3 Statistical Analysis Comparison Method

The core of the Statistical Analysis Comparison Method lies in the comparative analysis of annual monitoring data. By statistically calculating the quantitative differences between the previous year's monitoring data and the current year's monitoring data, it can quickly identify abnormalities in element data (such as sudden changes or missing data) and verify the rationality and completeness of the current year's monitoring results. It can be carried out through two key dimensions: total volume comparison and classification comparison.

2.4 Field Survey Method

The Field Survey Method involves on-site measurement or inspection, comparing the result data with field measurement results to determine whether the inspected data has errors or omissions, or to obtain the difference between the inspected data and the field measured data. This method is suitable for inspecting vector data through on-site measurement, such as verifying whether there are redundant or missing USM (Urban Spatial Monitoring) element data in urban territorial space through on-site inspection.

3. Technical Route

To better carry out the quality inspection of Urban USM data, a three-step inspection approach is adopted: overall preliminary inspection (computer-aided automatic inspection), detailed inspection (human-computer interactive inspection), and out-of-sample preliminary inspection. Specifically, computer-aided automatic inspection is first used to conduct an overall preliminary inspection on the batch results of each prefecture-level city. After all overall preliminary inspections are qualified, the sample size is determined by stratification and classification based on county-level survey areas from the batch results, and samples are selected for detailed inspection. Finally, aiming at universal and trending issues, an out-of-sample preliminary inspection is conducted on the non-sampled data by prefecture-level city. The technical route for the quality inspection of USM data results is shown in Figure 1.

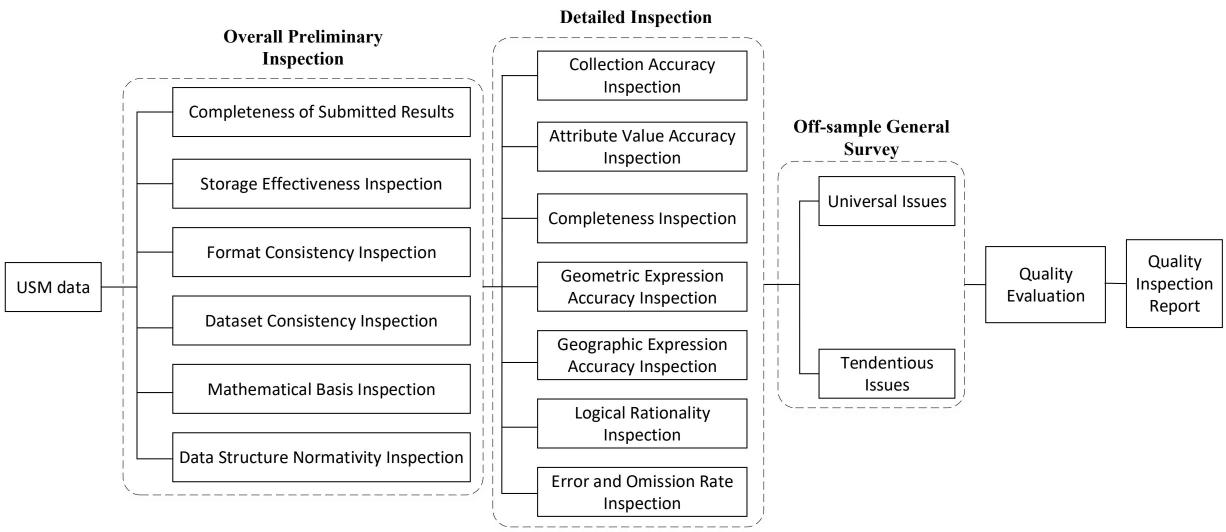


Fig.1 The Technical Route of Quality Inspection of the USM data

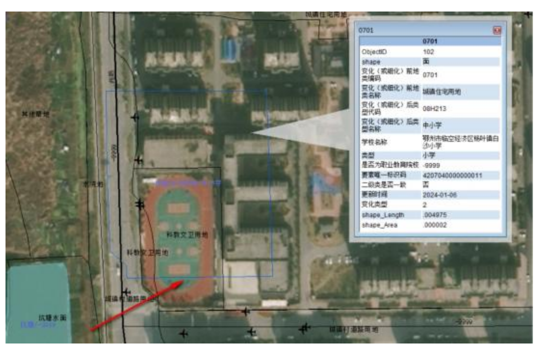
3.1 Overall Preliminary Inspection

In this study, quality inspection software was mainly used to conduct an overall preliminary inspection based on scheme customization technology for the batch results of each prefecture-level city. The automatic inspection based on scheme customization meets the requirements of efficient batch data quality inspection. It can set up quality inspection schemes for large batches of data results with multiple inspection items. By specifying the directory of large batches of data to be inspected, it can automatically complete inspections including spatial reference system checks, as well as logical consistency checks such as layer naming checks and data structure checks.

3.2 Detailed Inspection

The Detailed Inspection is conducted after the Overall Preliminary Inspection is qualified. On the basis of automatic inspection, manual intervention is required to check the attribute accuracy, completeness, and redundant or missing elements in the urban spatial monitoring (USM) data results.

3.2.1 Element Collection Accuracy Inspection: The Reference Image Comparison Method is adopted to check the superimposition issue between the positions of USM elements and images. As shown in Figure 2 (a), for refined and independent land use elements, the scope of the school parcel is inconsistent with the boundary of the change survey parcel; in Figure 2 (b), for supplementary elements, the road collection exceeds the superimposition limit with the image. Such problems reflect two aspects: on the one hand, the coordination with change survey data was not considered during the refined collection of elements, and supplementary elements (such as changes like on-site road rerouting) were omitted during collection; on the other hand, there are deviations in the understanding of technical regulations.



a) Inconsistent boundaries

b) Misalignment between features and images
Fig.2 Common Issues with Misalignment Between Elements and Imagery

3.2.2 Attribute Accuracy Inspection: The accuracy inspection of attribute values for refined elements and supplementary elements is conducted through human-computer interaction using the Reference Data Comparison Method and Internal Inspection Method. Typical problems are shown in Figure 3 (a): the "type" attribute of hospital elements is inconsistent with the reference data; Figure 3 (b): the "up-down direction" attribute of railways is unreasonably filled in. Such problems reflect the non-standard and inconsistent use of thematic data.

a) Inconsistent attribute assignment

b) Unreasonable attribute assignment
Fig.3 Common Issues with Inconsistent Attribute

3.2.3 Rationality Inspection Between Element Layers: Rationality inspection refers to the logical inspection between internal elements of USM element data or between data layers. The main problems are reflected in the following two aspects: as shown in Figure 4 (a), there is an area overlap between medical institution elements and welfare institution elements; Figure 4 (b), there are parcels collected in the urban building monomer surface layer, but the urban residential land surface at the same location is omitted; Figure 4 (c), the element collection is overly generalized, and sports venues that meet the index requirements are not represented separately.

a) Unreasonable area overlap

b) Omission in the collection of building surface layers

c) Excessive generalization of elements
Fig.4 Common Issues with Unreasonable Elements expression

3.2.4 Completeness Inspection: Completeness Inspection mainly focuses on whether there are omissions in updates at locations where changes occurred in the comparison of two phases of images, as well as cases of redundant elements or elements placed in wrong layers. Generally, methods such as on-site inspection, indoor comparison with field survey results, and inspection using reference materials like DOM are adopted. For example: omission in updating water purification plant elements; omission in collecting newly built airports and art gallery elements; omission in collecting large complexes in the commercial and service facility surface layer, etc.

3.2.5 Graphic Normativity Inspection: Graphic Normativity Inspection verifies and analyzes the correctness of the geometric expression of point, line, and surface elements by comparing with reference materials such as field survey verification data, remote sensing interpretation samples, and DOM in indoor checks. It uses program checks or calls data verification to analyze abnormal geometric figures of elements, including extremely small unreasonable surfaces, extremely short unreasonable lines, burrs, reverse lines, adhesion, self-intersection, jitter, etc.

3.3 Off-sample General Survey

For the inspection of urban territorial space monitoring data results, it is obviously insufficient to evaluate the quality only through detailed inspection of samples taking county-level survey areas as units. Considering the application needs of urban territorial space monitoring data results, it is necessary to conduct 100% inspection on the prefecture-level cities involved in the results to comprehensively judge the quality of the results. The off-sample general survey of USM data results is carried out for the off-sample regional scope results taking prefecture-level cities as units, mainly adopting three methods, namely, 100% detailed inspection for universal and tendentious problems in the results. The main problems found in the off-sample general survey of urban territorial space monitoring data results are as follows: (1)Attribute accuracy: inconsistency between the filling of element attributes and reference materials; (2)Element normativity: inconsistency between urban area scope and technical requirements, unreasonable collection of expressway entrances and exits, incorrect collection of driving schools as parking lots, inconsistency between the scope of refined independent land use elements and the boundaries of changed survey patches, etc.; (3)Element completeness: omission in updating industrial facility elements such as water plants, omission in collecting newly built airports, omission in refined collection of sports complexes that meet the index requirements, etc.

4. Case analysis

4.1 General Situation of the Survey Area

In 2025, China’s urban space monitoring project adopts the previous year’s national land change survey data as the base map. On this foundation, supported by high-resolution remote sensing images of the second quarter of 2025, the latest relevant thematic data, and combined with field surveys and other work, urban space monitoring is implemented across 170 prefecture-level cities. This monitoring work can effectively clarify the total scale of urban construction, land use composition, infrastructure conditions and service functions, and provide solid data support for territorial spatial planning compilation, urban physical examination and evaluation, land use regulation, and other territorial spatial governance practices. As a critical link in the urban space monitoring project, deliverable quality inspection features rigorous procedures and high complexity. The project involves 20 production and operational institutions, covering 170 prefecture-level administrative units with a total area of approximately 6 million square kilometers. It is characterized by a tight schedule, massive workload, complex technical indicators, heavy tasks, extensive manual inspection items and stringent technical requirements. At present, mainstream quality inspection software boasts powerful graphic inspection functions, enabling programmed automatic inspection of standardized items such as feature topological consistency, graphic normative compliance, and attribute structure standardization. However, inspection items requiring subjective judgment, including the completeness and correctness of feature updates as well as the accuracy of attribute content, still rely on manual verification. Traditional manual inspection is low in efficiency and suffers from inconsistent evaluation criteria. Therefore, carrying out technological innovation on the basis of existing inspection methods is of great significance for improving inspection efficiency and guaranteeing the quality of final deliverables.

4.2 Implementation of Quality Inspection Technology

The quality inspection software for urban space monitoring deliverables supports automatic batch processing inspection and conducts an overall general survey through automatic batch analysis of results across 170 prefecture-level cities. On this basis, one sample of county-level survey area is selected from each prefecture-level city for human-computer interactive inspection, and a general summary investigation is finally carried out on common and tendentious defects in the deliverables. Secondly, spatialized inspection records are generated by positioning points; meanwhile, all inspection records are classified and organized in accordance with the sequence of inspection parameters, and unified warehousing of results is realized, achieving spatial management of inspection problem records relying on database technology. Thirdly, the automated quality evaluation of inspected results is resolved. Quality assessment of individual unit deliverables is accomplished with the support of the established quality database. Finally, the software meets the demands of high efficiency, flexibility, applicability and large-scale operational production. Through the design of automatic batch inspection workflows for massive volumes of data based on standardized quality inspection schemes, automatic quality checking for bulk datasets is realized, which greatly enhances the efficiency of quality inspection work for large-area urban space monitoring data achievements. The interface of the USM data product quality inspection software based on the customized scheme is shown in Figure 5.

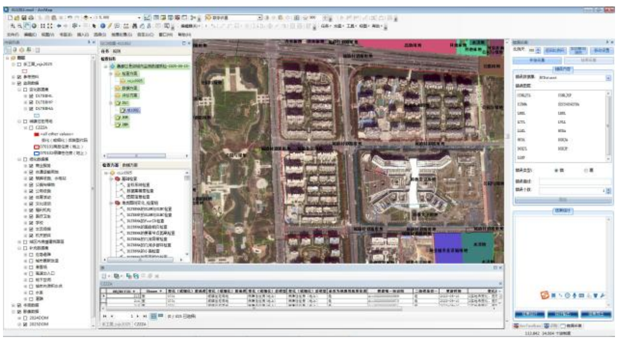


Fig.5 Inspection Based on Custom solutions

4.3 Quality Inspection Results

Adopting the scheme-customized method proposed in this paper, overall general inspection and detailed inspection are implemented for urban space monitoring results. Combining automatic batch inspection with human-computer interactive inspection, the inspection and evaluation of data deliverables covering 170 prefecture-level cities are efficiently completed, and the common problems existing in sample results are clarified. The statistical chart of error and omission rate indicators for the 170 samples is shown in Figure 6.

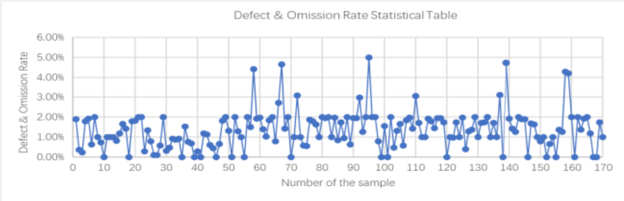


Fig.6 Statistical Table of Error and Omission Rate Indicators

Finally, the urban space monitoring data covering 170 prefecture-level city survey areas with a total area of approximately 6 million square kilometers have been inspected. The results verify that the technical route proposed in this paper is feasible, and the quality evaluation findings are objective.

5. Conclusion

Based on an analysis of the differences in inspection between urban territorial space monitoring data results and basic surveying and mapping data results, this paper extracts automatic inspection items from urban territorial space monitoring data results, realizes automated inspection of some quality sub-elements, and improves the efficiency of quality inspection for large batches of data results. For inspection items such as element collection accuracy, attribute accuracy, and completeness, methods including reference data comparison, statistical analysis and comparison, field measurement, and computer interactive inspection are adopted. These measures ensure the uniformity and objectivity of quality evaluation for urban territorial space monitoring data results, and guarantee the high-quality and efficient completion of quality inspection tasks for major urban territorial space monitoring projects.

Acknowledgements

The authors would like to thank the valuable comments from anonymous reviewers. This research was supported by the Satellite Remote Sensing Operational Support Service System for Natural Resources No.12113400000019002.

References

Checa, B. C., Haza, L. D. P. J. M., Aliaga, C. E. 2024. Development of a methodology for the evaluation of environmental equity at urban level with high spatial resolution. Case study in Valencia (Spain). Environ. Sustain. Indic., 22, 100375. https://doi.org/10.1016/J.INDIC.2024.100375

Chen, J., Wu, H., Zhang, J. X., et al. Directions and tasks for constructing the technical system of natural resources survey and monitoring[J]. *Acta Geographical Sinica*, 2022, 77(5): 1041-1055.

Ge, J., Zhang, J. X., Han, W. L., et al. Discussion on ontology design of knowledge graph for quality inspection of natural resources survey and monitoring results[J]. *Geomatics World*, 2022, 29(5): 39-42.

General Administration of Quality Supervision, Inspection and Quarantine of P.R.C., Standardization Administration of P.R.C.. GB/T 18316-2008, Specifications for quality inspection and acceptance of digital surveying and mapping achievements[S]. Beijing: *Standards Press of China*, 2008.

Guo, Z. F. Quality issues and quality control suggestions of urban territorial space monitoring results[J]. *Resettlement*, 2023(22): 143-145.

Hao, Z., Lin, L., Post, J. C. 2024. Monitoring the spatial–temporal distribution of invasive plant in urban water using deep learning and remote sensing technology. Ecol. Indic., 162, 112061. https://doi.org/10.1016/J.ECOLIND.2024.112061

Luo, T. X., Liu, R. X., Duo, M. X. Analysis of quality influencing factors and control methods for urban territorial space monitoring[J]. *Technology Innovation and Application*, 2023, 13(22): 138-141.

Mao, W. J., Zhang, L., Zhang, L., et al. Quality inspection of geographical national conditions element data results[J]. *Science of Surveying and Mapping*, 2017, 42(2): 35-39.

Ministry of Natural Resources. Master plan for the construction of natural resources survey and monitoring system[R]. 2021-01-20.

No. 1694 (2025) of the General Office of the Ministry of Natural Resources: Implementation Plan for Quality Inspection and Acceptance of Urban Territorial Space Monitoring Results[EB/OL]. Beijing: *General Office of the Ministry of Natural Resources,* 2025.

Wu, L. J. Brief discussion on refinement and supplementation of urban spatial information in urban territorial space monitoring[J]. *Geomatics and Spatial Information Technology*, 2023, 46(9): 96-99.

Zeng, C. Q., Zhang, J. F., Zhang, J., et al. Preliminary study on urban territorial space monitoring[J]. *Urban Geotechnical Investigation & Surveying*, 2024(2): 1-8.

Zheng, J. W., Deng, X. F. Analysis and discussion on quality inspection issues of urban territorial space monitoring results[J]. *Geospatial Information*, 2023, 21(10): 131-134.

Zhao, S. Analysis and discussion on quality inspection issues of urban territorial space monitoring results[J]. *Planning and Management*, 2023: 38-40.