KEY TECHNOLOGIES FOR 1:10,000 RAPID MAPPING BASED ON GF-7 SATELLITE

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KEY WORDS: GF-7, 1:10,000, Information Extraction, Cartographical Generalization, Intelligent Mapping.

ABSTRACT:
In order to solve the problems of low efficiency, high cost and long cycle of the traditional 1:10000 basic geographic information data production method (aerial photography combined with field mapping), this paper proposes a 1:10000 rapid mapping method based on GF-7 satellite data. It solves the key technical difficulties of automatic information recognition, extraction, integration and mapping of water body, building, road, vegetation, contour, and other elements. And an automatic software system of “image -> patch -> data -> map” is developed, which realizes the rapid production of 1:10000 basic geographic information data products and improves the ability of high-precision basic geographic information resource construction.

1. INTRODUCTION

Basic geographic information is an indispensable basic and strategic information resource for national economic construction, social development, national defense construction and ecological protection. It is also the spatial framework and information base for natural resources investigation and monitoring. The construction of digital China, the development of digital economy and the high-quality governance of natural resources urgently need 1:10,000 basic geographic information data with good currency. However, the traditional 1:10,000 mapping work, which based on aerial photography and field survey has a large workload, high cost and long cycle. Therefore, it is urgent to build a new 1:10,000 rapid mapping technology system.

China’s first optical stereo mapping satellite with a sub-meter resolution, Gaofen-7 (GF-7), was successfully launched in 2019. It can provide clearer details of the ground objects. Its orbit period is 97 minutes and the revisit period is 3 days, which can provide more timely remote sensing data. The image width is 70 kilometers, which can cover a wider area. The number of satellite bands reaches 16, which can provide richer ground object information. So, GF-7 satellite is very suitable as a data source for 1:10,000 mapping. However, because GF-7 satellite has a lot of information and large amount of data, it also greatly increases the difficulty of image automatic interpretation and rapid mapping in 1:10,000 mapping.

This paper focuses on the automated information recognition, extraction, cartographical generalization and rapid mapping of elements such as water bodies, buildings, roads, vegetation, contour lines and other elements in 1:10,000 data based on the characteristics of domestic GF-7 satellite data. A complete set of software system based on GF-7 satellite 1:10,000 mapping ‘image->patch->data->map’ is developed to support the rapid production of 1:10,000 basic geographic information products and improve China’s ability to obtain high-precision basic geographic information resources.

2. MAIN METHODS

2.1 This study proposed a feature recognition method with adaptive deep learning model assisted by feature expression characteristic knowledge base, to realize the automated patch extraction of typical elements in 1:10,000 mapping based on GF-7 satellite.

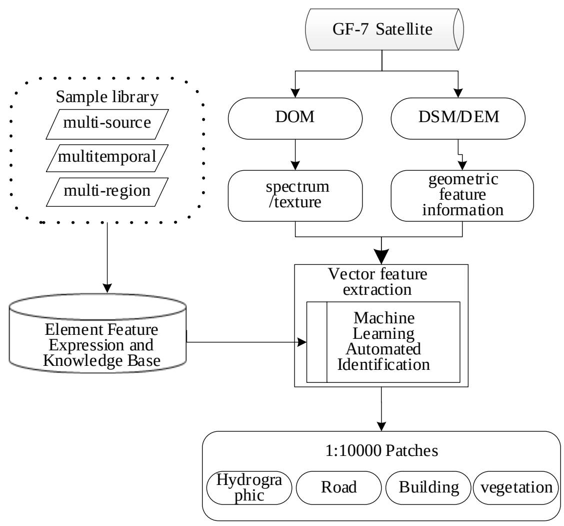

Figure 1. Process of element automatic extraction on GF-7 satellite

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2.1.1 Build a feature extraction sample library tailored to Gaofen-7 satellite remote sensing data: This paper designs a land cover classification-driven sample library model that contains sample spatial location, temporal phase, resolution, spectrum and other information for precise management and application. Based on the 1:10,000 basic geographic information classification system, the study established an extensible sample classification framework to overcome the cognitive limitations of interpretation models due to incomplete types in the sample library. This paper also developed a “spatial-temporal-semantic” composite indexing method for sample organization, which enhances the retrieval efficiency and accuracy of the sample library; and a sample distribution strategy that accounts for land cover types, geomorphic landscape types, and temporal types, which ensures that the samples in the sample library spatiotemporally cover the geographic environmental features of different regions, and boosts the generalization ability and robustness of deep learning models.

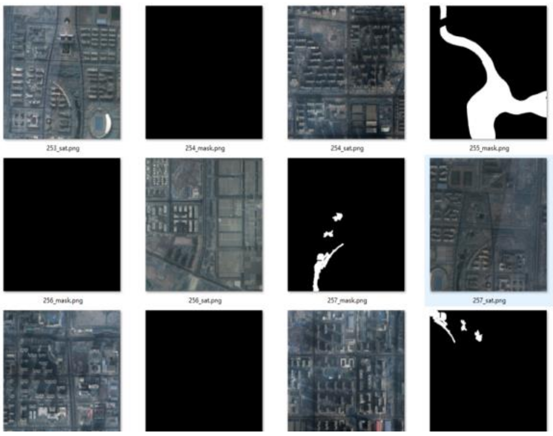

Figure 2. Example of water body extraction sample library

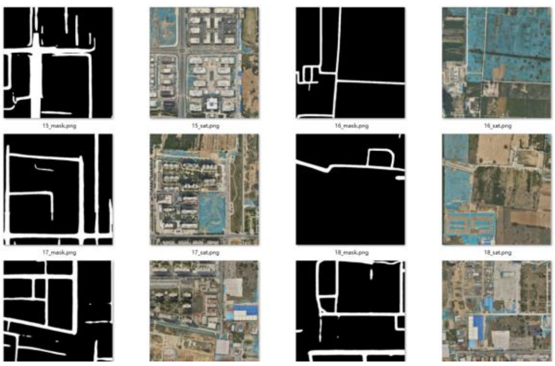

Figure 3. Example of road extraction sample library

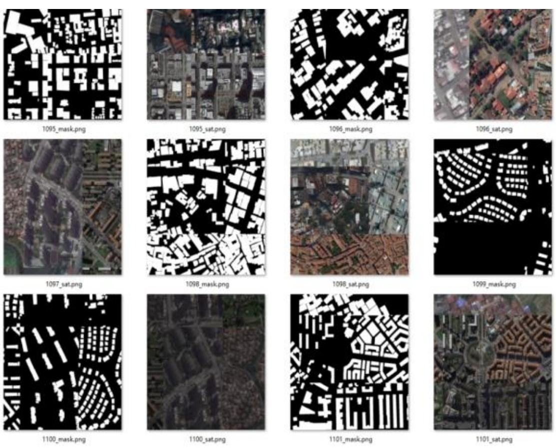

Figure 4. Example of buiding extraction sample library

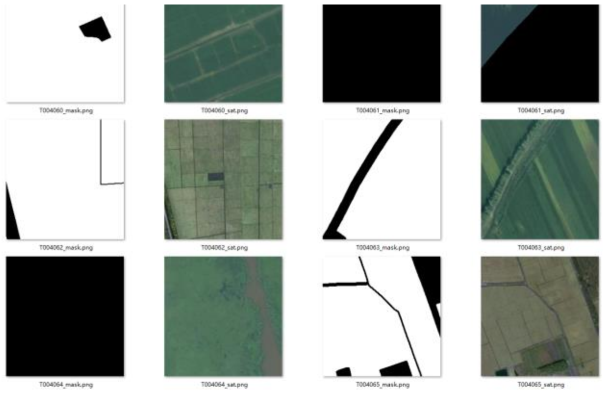

Figure 5. Example of vegetation extraction sample library

2.1.2 Build a knowledge base of feature expressions with spatial and semantic constraints for geographic objects: Based on geographic expertise, this paper systematically examine and organize the spatial attributes of various geographic objects, such as their location, shape, distribution, relationship, and association, and derive the spatial constraint rules for each object type. It also create diverse scenarios for geographic object extraction and identify the deep semantic links within them. By integrating the constraint rules and semantic information, a knowledge base of feature expressions for geographic objects is constructed, which enhances the accuracy of automatic extraction by deep learning models.

2.1.3 Develop feature-constrained machine learning for automatic ground object extraction: To address the low success and accuracy of existing remote sensing intelligent interpretation using the Gaofen-7 satellite, which fails to meet the 1:10,000 mapping requirement, this paper use the Gaofen-7 satellite feature extraction sample library from the project to train a set of deep learning models for different ground objects. These models can adaptively adjust to the extraction targets and enhance their generalization ability. Moreover, the paper incorporates the spatial and semantic information of the ground objects from the feature expression knowledge base of the project into the deep learning models and build a feature-constrained machine learning technique for automatic ground object extraction, which significantly boosts the success and accuracy of extraction.

2.2 This study created cartographical generalization method based on mathematical morphology and attribute fusion technology based on crowd sourced geographic information, to achieve automated data generalization of 1:10,000 patches extracted from GF-7 satellite.

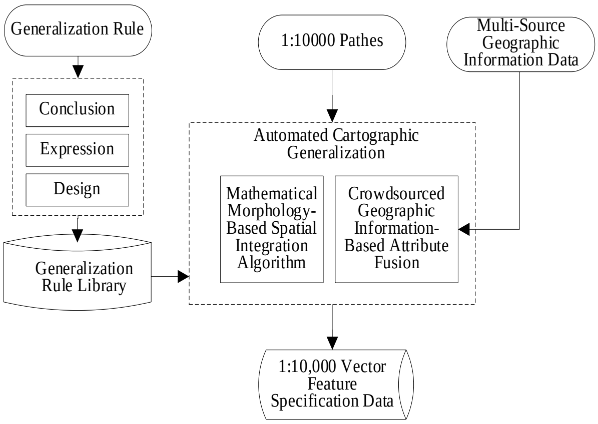

Figure 6. Process of automated data generalization based on GF-7 satellite

2.2.1 Build a generalization rule base for automatic feature extraction from Gaofen-7 satellite images: Systematically analyse the spatial and semantic features of typical 1:10,000 elements such as water bodies, buildings, roads, vegetation, contour lines, etc. that are automatically extracted from Gaofen-7 satellite images, and according to the national standard "Basic Geographic Information 1:10000 Topographic Feature Data Specification", identify the content that requires comprehensive processing of graphics and attributes for the extracted information, and design appropriate comprehensive processing metrics, operator combinations, knowledge rules and other rules for different element types and regional features, and construct a generalization rule base using the "rule + rule set" method, which supports automatic data integration.

Rule Set	Rule
Traffic	Road surface edge treatment
	Road centerline processing
Residential areas and facilities	Residential ground edge treatment
	Residential selection
	Rresidence level changes
	Block processing
	Right-angled housing
Hydrographic Feature	Water surface edge treatment
	Water surface selection
	Water structure line processing
	Linear water system treatment
Vegetation and soil	Vegetation surface edge treatment
	Vegetation surface selection
	Vegetation level change
	Vegetation surface element merge processing
	Vegetation surface hole treatment
Landform	Contour simplification
	Contour curved simplification
	Contour smooth

Table 1. Generalization rule library.

2.2.2 Develop a mathematical morphology-based spatial integration algorithm with geographic features: To address the issues that the extracted ground object graphics from remote sensing images do not meet the 1:10000 basic geographic information data expression standards, and that the current spatial integration methods have low automation and quality, the study analyses the geometric shapes, spatial distributions and other geographic features of various ground object elements, and design appropriate structural elements for different features, using mathematical morphology operators such as erosion, dilation, opening, closing, skeletonization, reconstruction, etc., along with the rule base, the paper build a spatial integration algorithm that automatically simplifies, smooths, aggregates and other processes the ground object graphics, while preserving the geographic features and spatial relations of the elements, significantly enhancing the spatial integration efficiency and quality.

2.2.3 Develop crowdsourced geographic information-based attribute fusion: To address the missing attribute information of ground objects automatically extracted from remote sensing images, this paper proposes a technical route of using crowdsourced data mainly from OSM data as a supplementary attribute source, and compares it with the basic geographic information 1:10000 topographic feature data specification, systematically analyses the content, structure and other information of crowdsourced data, establish a multi-source heterogeneous data mapping model, and develop a rule-based model automatic conversion technology, which normalizes the crowdsourced data model; the paper develop a spatial matching technology of homonymous entities with "geometry + topology + semantics" multi-modes, construct a homonymous entity association relationship, and fuses the attribute information, which effectively solves the missing attribute information of automatic ground object extraction.

2.3 This study created an object-oriented intelligent symbol system and rule-driven intelligent mapping technology to achieve fast mapping of 1:10,000 comprehensive data based on GF-7 satellite.

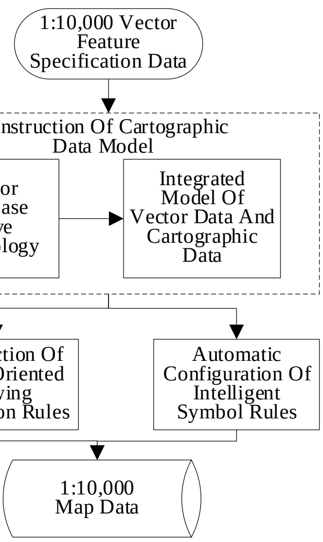

Figure 7. Process of intelligent mapping based on GF-7 satellite

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2.3.1 Develop a component-based intelligent symbol system with flexible editing: For point, line and polygon symbols of 1:10,000 geographic data, research and record their reasonable components, attributes, configurations, associations and edits according to topographic map standards. Based on this system, automatically optimize symbol configurations by calculating component positions.

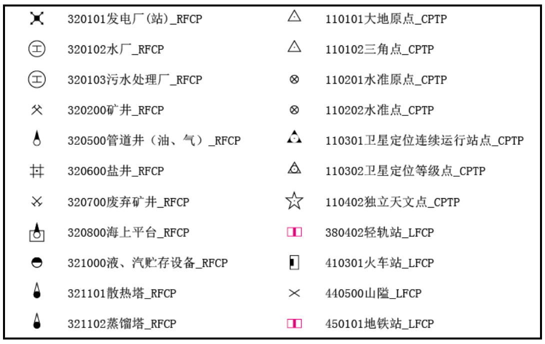

Figure 8. Point map symbols

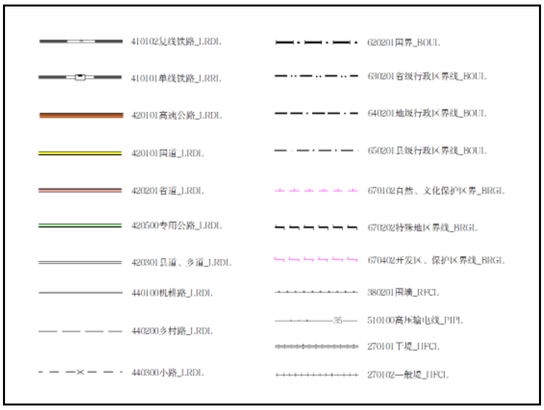

Figure 9. Line map symbols

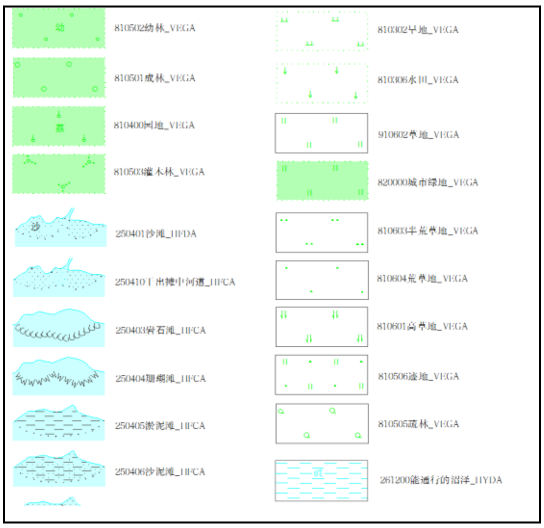

Figure 10. Area map symbols

2.3.2 Design an integrated storage model and modeling method for vector features automatically extracted by GF-7 and 1:10,000 mapping features. Research and analyze the mapping expression characteristics of water bodies, buildings, roads, vegetation, contour lines and other features in 1:10,000 basic geographic data, and establish an integrated model of terrain features and mapping features by extending the physical structure and reorganizing the logical structure of basic geographic data, and creating and maintaining the association relationship between terrain information and mapping information. Mapping data is derived from basic geographic data through driving technology, and various mapping representations such as symbols, annotations, decorations, etc. can be edited and modified without changing the terrain data, realizing the unified management of basic geographic data and mapping data, and supporting the synchronous update of mapping data with terrain data.

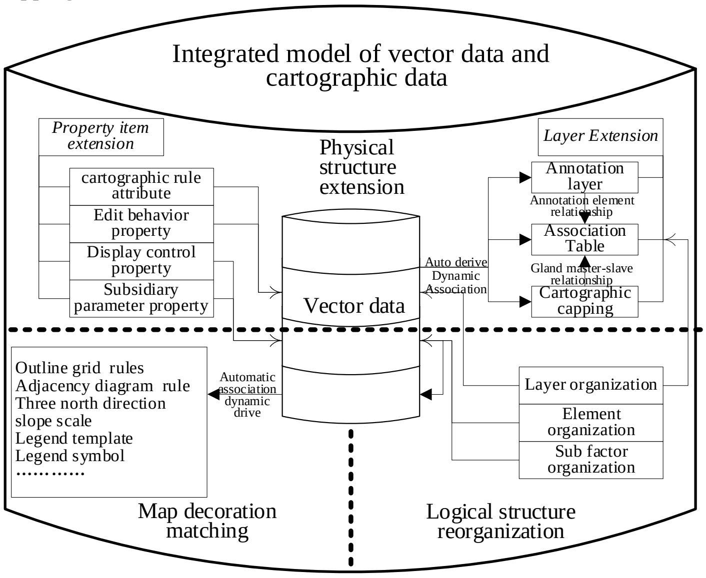

Figure 11. Process of rapid mapping based on GF-7 satellite

2.3.3 Develop intelligent mapping technology with map optimization rules and conflict detection quality control. For 1:10,000 basic geographic information, an intelligent symbol system and an integrated model enable intelligent configuration and rapid mapping. The technology includes map optimization rules and algorithms for symbols, annotations, and outline embellishments, as well as feature conflict detection quality control. Symbols are automatically configured based on feature attributes, overlay priority rules of "layer + feature class + symbol component", and symbol expression optimization based on spatial topology. Annotations are automatically derived and positioned based on feature importance, and optimized based on spatial and non-spatial joint operations. Outline embellishments are automatically derived from data metadata and optimized based on standard map framework real-time positioning. To ensure map quality, spatial relationship consistency constraints are used to detect map feature errors such as overlay, contradiction, gap, or too close distance.

2.4 This study established a set of software systems for fast mapping of 1:10,000 GF-7 satellite images to meet engineering application needs.

Integrated the previous technical methods, this study developed a set of 1:10,000 fast mapping software systems covering the entire process of feature recognition, extraction, generalization and mapping production. The software is based on the technical route of "image -> patch -> data -> map" for 1:10,000 mapping based on GF-7 satellite. Figure.12 shows the whole process of rapid mapping. A standard system covering extraction procedures and product specifications was formulated, and a set of software systems covering the entire process of mapping was developed. It has been applied and demonstrated in many national and provincial departments and supported the completion of many special projects, significantly improving China's ability to produce high-precision basic geographic information data

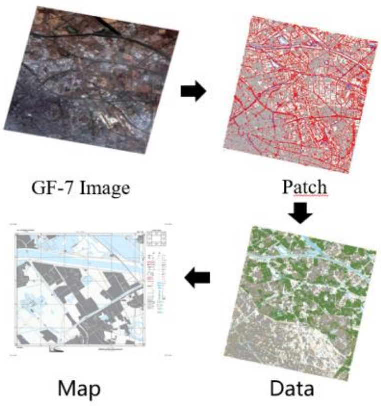

Figure 12. Process of rapid mapping based on GF-7 satellite

3. RESULTS AND DISCUSSION

In order to verify the application effect of the key technologies for fast mapping of 1:10,000 based on GF-7 satellite proposed in this paper, 27 trial productions of 1:10,000 basic geographic information data were carried out using the 1:10,000 fast mapping software system developed in this study. The trial production area covers various landform types that has typical representativeness, such as plains, mountains, hills and high mountains. The analysis of the trial production results shows that the success rate and accuracy of feature automation extraction of the technical methods in this paper are generally better than 80% (Table 2), and the comprehensive processing efficiency has been improved by 100% (Table 3), and the mapping efficiency has been improved by more than 50% overall (Table 4).

Category	Content	Type	Success rate	Accuracy
Hydrographic Feature	Rivers	Line	92%	84%
	Ditches	Line	91%	86%
	Lakes	Area	95%	85%
	Ponds	Area	94%	81%
	Reservoirs	Area	91%	85%
	Ocean elements	Area	96%	90%
Residential areas and facilities	Building (simple)	Area	90%	86%
	Building (complex)	Area	84%	76%
	Fence	Line	81%	80%
Traffic	National road	Line	89%	86%
	Provincial road	Line	91%	84%
	County road	Line	88%	84%
	Township road	Line	70%	65%
	Parking lot	Area	81%	76%
	Airport	Area	78%	74%
Landform	Contour line	Line	99%	98%
	Elevation annotation	Point	95%	90%
Vegetation and soil	Cultivated land	Area	88%	82%
	Forest land	Area	83%	74%
	Grassland	Area	86%	81%
	Scattered trees	Point	72%	71%

Table 2. Success rate and accuracy of automation extraction.

Category	Traditional efficiency	Achieving efficiency
Hydrographic Feature	1 day per sheet	0.5 day per sheet
Residential areas and facilities	1.5 day per sheet	0.5 day per sheet
Traffic	1 day per sheet	0.5 day per sheet
Landform	3-5 day per sheet	0.5 day per sheet
Vegetation and soil	2 day per sheet	1 day per sheet

Table3. Data comprehensive processing efficiency indicator.

Cartographic process	Traditional efficiency	Achieving efficiency
Symbol configuration	50%	80
Map decoration	50%	95%
Symbol optimization	50%	80%
Map conflict	50%	80%

Table 4 Automation rate indicators for intelligent mapping.

4. CONCLUSIONS

This paper studies the key technologies of 1:10,000 rapid mapping such as information extraction, cartographical generalization and intelligent mapping based on the satellite GF-7. It well meets the needs of 1:10,000 basic geographic information resource construction. At the same time, it can also meet the urgent needs of high-precision geographic information in China's natural resource supervision, urban and rural construction, agricultural statistics and other fields, and serve the high-quality development of China's economy and society.

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