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Technology Research and Platform Development of Crowdsourcing-driven Geographic Information Update

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Traditional methods for updating geographic information data involve long cycles and a large amount of manual work, making it challenging to maintain the data's timeliness and limiting its utility and scope. Timely updates require rapid change detection. With the development of aerial and satellite sensors, as well as Internet and social sensing technologies, rapid change detection becomes possible, shifting the approach from a "push-scan" method to a "change-discovery-driven" model. In this study, we introduce a change-discovery-driven geographic information update model using crowdsourced data, supported by a change-detection platform. The platform consolidates change detection, standardized processing, and shared services to facilitate timely updates. For the first time, multiple channels for change detection are comprehensively established, including automatic change detection from remote sensing images, web crawlers, crowdsourcing, and business information aggregation. These methods efficiently extract change information and provide services in the form of change spots, offering robust support for rapid geographic information updates. This approach has been applied in basic mapping updates and land change surveys, enabling quick identification of changes in geographic information. The change-discovery-driven model significantly enhances the efficiency of geographic information updates, reducing manpower and minimizing repetitive operations.

1. Introduction

Traditional methods for updating geographic information data by surveying and mapping one by one, which can be called the "push-scan" updating model, are characterized by long cycles and low efficiency, making it challenging to ensure data timeliness, which in turn impacts its utility and application scope. Timely updates require rapid change detection. With the development of aerial and satellite sensors, as well as Internet and social sensing technologies, rapid change detection becomes possible.

Currently, various regions are extensively conducting research on improving the timeliness of spatiotemporal information through change detection. Some countries have launched

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surveying and mapping services related to change detection. The Ordnance Survey in the UK stipulates that any disappearance of old buildings, appearance of new buildings, or changes in place names must be promptly recorded. If there are 300 units of change within a quarter square kilometer, a new map must be redrawn to ensure that users can obtain the latest information in a timely manner. From the perspective of building national spatial data infrastructure and spatial data exchange networks, whether led or coordinated by national government departments, various regions encourage broad participation from all sectors of society, including not only data production enterprises and government departments, but also various users, developers, research and education institutions, and interested enterprises. In Australia,(1) based on the sharing of geographic information among various levels of government and departments, avoiding duplicate mapping, the overall benefits of geographic information resources have been considerably utilized, and the timeliness of results has been improved. Cities such as Beijing, Wuhan, Hunan, and Xinjiang are exploring rapid geographic information updating techniques based on change detection.(2–4) The primary approaches involve detecting changes from existing mapping results and geographic information databases,(5,6) aerial and satellite imagery,(7–9) Internet-sourced information,(10–13) and crowdsourcing. (14–16)

With multitemporal images, a large number of research results have shown that the land cover change-detection method based on deep learning has significant advantages(17) in terms of manpower investment, operational efficiency, and achievement quality. By using web crawlers to automatically retrieve information on major projects or place names, update clues can be quickly discovered. Through text analysis and geographic matching, the elements that have changed and the approximate areas where the elements have changed can be determined. Online text information can automatically detect changes in some geographic information elements, improving the efficiency and accuracy of geographic information data updates. Jiangsu Province(10) has explored and studied the technical route to quickly discover the changes of various important basic geographic information in the province. It regularly collects information classified from government websites, news media websites, Internet maps and other Internet resources by using technologies such as crawlers and application programming interfaces (APIs). Crowdsourcing technology(18) is a new model for obtaining geographic data, where the public becomes information providers rather than just users of geographic information services. By utilizing the participation of crowdsourcing users, network mapping, online mapping, and disaster acquisition and management can be achieved. The collected data has the advantages of low cost and high timeliness, which can lead to rapid extraction and timely updating of geographic information.

However, in practical applications, the single-change-detection method has certain limitations, such as difficulty in obtaining comprehensive information based on network and crowdsourcing modes, problems in extracting small surface changes owing to image resolution limitations, and difficulty in extracting change attribute information from aerial and satellite imagery. By comprehensively utilizing multiple change-monitoring methods and sources, they can complement and corroborate each other, resulting in more comprehensive and credible outcomes.

Therefore, in this study, we explore a geographic information update model driven by multisource change detection. It aggregates information from diverse channels, leveraging the automatic interpretation of remote sensing imagery, internet information, crowdsourcing, and existing business data to build a change-detection platform. This platform supports rapid geographic information updates, enhancing both efficiency and accuracy.

2. Crowdsourced Change-discovery-driven Geographic Information Update Model

To improve the timeliness of geographic information, a crowdsourced change-discovery-driven update model has been developed, as shown in Fig. 1. This model incorporates a change-detection platform that standardizes the process from the aggregation and processing of change-detection data to its application in various services.

Multiple channels for change-detection have been established, utilizing methods such as automatic change detection from remote sensing images, web crawlers, crowdsourcing, and business information aggregation. These methods serve as a foundation for surveying, investigation, and monitoring activities, enabling the dynamic updating of geographic information.

2.1 Information sources and update cycles

Crowdsourced change-detection data can be categorized into the following four main types.

Automatic Change Detection Based on Satellite and Aerial Remote Sensing Imagery: This method utilizes remote sensing images and auxiliary data covering the same surface area across different time periods to identify and analyze changes. It enables both qualitative and

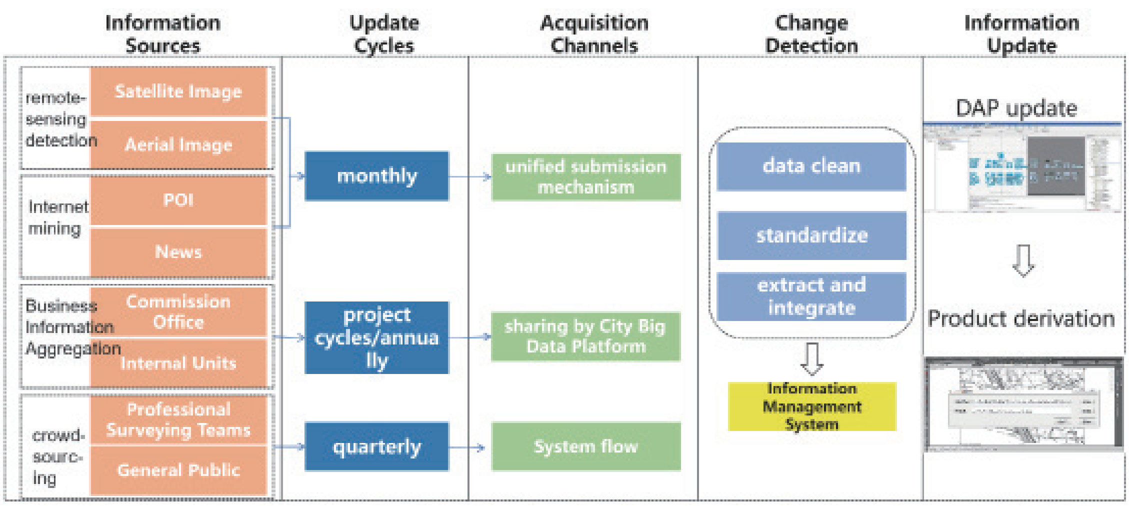

Fig. 1. (Color online) Crowdsourced change-discovery-driven geographic information update model.

quantitative insights into changes in land cover or phenomena, using specific algorithms to automatically detect changes on a large scale. This method can be updated monthly.

Internet Crawlers for Mining Point of Interest (POI) and News: Geographic information is automatically collected from the Internet and social media through web crawlers, gathering both structured and unstructured data on a large scale. This provides essential support for analyzing geographic information changes. This method can also be updated monthly.

Shared Business Information from Government Commissions, Bureaus, and Internal Units: This approach achieves information sharing between government departments, including grid management, housing, and transportation sectors, for accurate updates of key land features. Data aggregation is based on project cycles or updated annually.

Crowdsourced Information from Professional Surveying Teams and the General Public: By involving both professionals and the public in data collection, this method shifts geographic information updates from relying solely on professionals to a combined effort. To encourage participation, a reward mechanism for users can be developed. This method is updated quarterly.

Each of these sources plays a role in the dynamic updating of geographic information, ensuring data remains timely and relevant.

2.2 Channels for crowdsourced data acquisition

Channels for aggregating crowdsourced change-detection information vary by data source:

Business Information is shared through platforms such as city big data, multi survey integration services, and urban code systems. Automatic Change Detection from Remote Sensing Imagery and Internet Crawlers are collected through a unified submission mechanism. Crowdsourced Change Information is gathered via designated systems. These channels ensure that change-detection data are aggregated into the change detection information management system on a monthly, quarterly, and annual basis.

2.3 Crowdsourced data change detection

The crowdsourced data undergoes the following standardized process.

Preprocessing: Regular submissions are formatted and coordinate-transformed.

Data Cleaning: Classification, deduplication, and extraction of change information are performed.

Standardization and Integration: Data is standardized, extracted, and integrated to produce change products on a monthly, quarterly, or annual basis.

The standardized change information table is shown in Table 1.

2.4 Crowdsourced change-discovery-driven geographic information update

In geographic information updating, the previous year's data serves as the baseline, with updates made based on detected changes. For example, in the context of basic surveying and mapping updates, change detection products are integrated with geographic entity editing tools

Table 1
Change-discovery information criteria table.

Field name	Field type	Field length	Instructions
Unique coding of patches	LONG	50	Unique code, area code + sequential number, example: "110108001"
District	TEXT	50	
Street	TEXT	50	
Community	TEXT	50	
Change node time	DATE	50	
Prechange information sources	TEXT	255	
Postchange information sources	TEXT	255	
Type of change	TEXT	18	
Change production time	DATE	50	

to update the new basic surveying geographic entities. Topographic map products are then derived using seamless map generalization software, completing the surveying business updates.

3. Key Technologies for Change Detection Based on Crowdsourced Channels

Using the crowdsourced change-discovery-driven geographic information update model, key technological research has been conducted across different data sources, including remote sensing imagery, internet mining, business information aggregation, and crowdsourcing.

3.1 Automatic change detection based on remote sensing imagery

To support practical production applications, a generalized, scalable, and deep-learning-based change-detection solution using remote sensing imagery has been developed, as shown in Fig. 2.

Sample Library Construction: In line with practical production needs, various update sample standards have been established. A sample library for change detection is constructed by annotating aerial or satellite images based on these standards. Existing data update results can also be used to obtain sample data.

Model Training and Transfer: With self-developed or publicly available deep learning models (e.g., U-net), autonomous model training is performed. These models can be transferred and adapted for different multi-element training scenarios.

Change Detection: The trained models are used to extract areas of change, which are then saved for further analysis and updates.

3.2 Change information mining based on internet crawlers

Existing POI and news data contain valuable geographic and change information. By extracting thematic content and change-related data from the internet, unconventional data sources are provided to the change-detection platform, forming a robust solution for internet mining technology, as shown in Fig. 3.

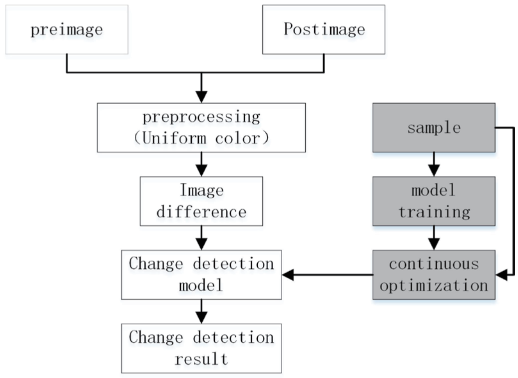

Fig. 2. Automatic change-discovery technology flow chart from remote sensing images.

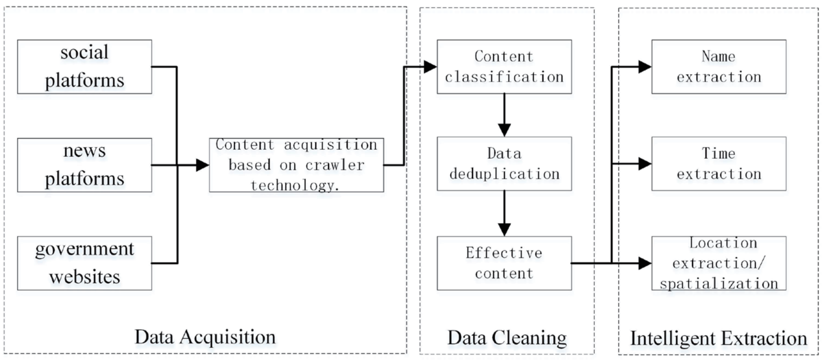

Fig. 3. Internet mining change-discovery technology flow chart.

(1) Data Acquisition: Data are gathered using internet crawler technology, primarily from social platforms (e.g., Weibo, Toutiao), news sites, and government websites (e.g., Natural Resources Commission, Construction Committee).
(2) Data Cleaning: The collected data are classified and filtered, with irrelevant content removed and duplicates eliminated. Classification involves extracting keywords and using summary extraction and text classification. Deduplication includes direct deduplication and text similarity analysis.
(3) Intelligent Extraction of Change Information: Natural language processing (NLP) is employed to extract change-related information, such as project names, dates, and locations. NLP is also used to accurately identify entity names, times mentioned in news, and addresses, converting this information into spatial data.

3.3 Business information aggregation

To improve data sharing across commissions, offices, and internal units, data-sharing channels have been expanded to collect industry management and business data, extracting relevant change information. A mechanism for the joint use of spatial geographic information between government bodies is established, ensuring access to industry change data.

(1) Urban Components, Housing, and Case Reporting: Through the government's big data platform, real-time retrieval and aggregation of updates on urban components, housing changes, and case reporting within grid units are facilitated, enhancing urban grid management.

(2) Housing and Construction Data: Real-time retrieval of specialized data from the Municipal Commission of Housing and Urban-Rural Development includes housing completion records, rental information, affordable housing, demolitions, and underground space management, providing a comprehensive view of housing status.

(3) Traffic Management Data: Real-time retrieval of traffic data covers roads, bridges, rail transit, and associated facilities, supporting updates related to construction, maintenance, bridge inspections, and transit operations.

3.4 Crowdsourced change detection

To fully leverage social resources for geographic information maintenance, crowdsourcing tools have been developed for collecting change data. These tools allow for the release of data collection tasks and the reporting of change cases, involving both professional surveyors and the general public.

(1) Professional Surveyors: Specialized software (apps) enables professional surveying teams to mark and report areas where data are outdated or inaccurate, supporting targeted updates and maintenance.

(2) Public Engagement: The general public can view publicly accessible geographic information via a WeChat mini-program. By publishing survey tasks and enabling case reporting, in combination with a points and rewards system, public participation is encouraged, thereby stimulating the use, maintenance, and update of geographic information.

4. Design and Implementation of Crowdsourced Change-discovery-driven Geographic Information Update Platform

To implement the crowdsourced change-discovery-driven geographic information update model, key technological research into change detection via crowdsourced channels has led to the development of a comprehensive platform. This platform supports mobile- and browser-based interfaces, facilitating the entire process from crowdsourced data collection and processing to change-detection product management and service provision.

The platform consists of multiple systems, including professional change information collection software (apps), public change information collection software (WeChat mini-program), and a change-detection information management system.

4.1 Overall architecture

The change-detection platform is structured into five layers: infrastructure, data, service, function, application, and user, as shown in Fig. 4.

(1) Infrastructure Layer: This layer relies on both the internet and local area networks, comprising database servers and application servers. The internet end hosts the change-detection app for professional surveying teams and the WeChat mini-program for the public, while the local area network hosts the change-detection information management system.

(2) Data Layer: Data are divided on the basis of network segments (internet and intranet) and resource types, which include remote sensing detection datasets, internet crawler datasets, business information aggregation datasets, and crowdsourced datasets.

(3) Service Layer: This layer provides support services for various platform functions, including GIS services, query services, statistical analysis services, internet base map services, and file transfer services.

(4) Function Layer: The platform's core functions include inspection and verification tasks, data display and query, statistical analysis, and data distribution and download.

(5) Application Layer: The application layer features the change-detection app for professional surveying teams, the WeChat mini-program for the public, and the change-detection information management system. The app consists of an internet field verification tool and a

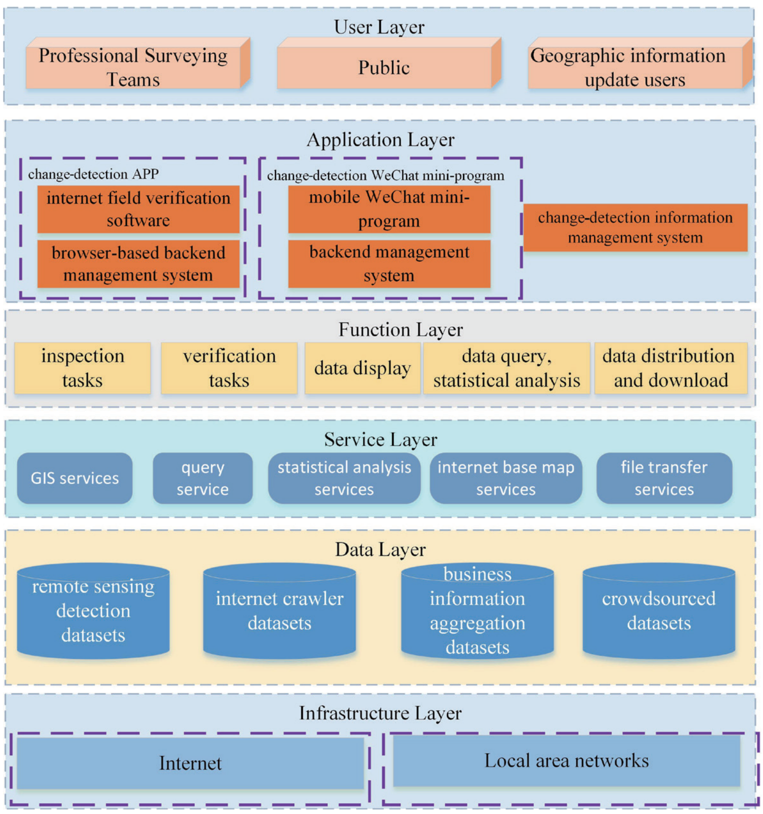

Fig. 4. (Color online) Platform architecture.

browser-based backend management system. The WeChat mini-program includes both a mobile mini-program and a backend management system.

(6) User Layer: The platform's users include professional surveying teams, the general public, and those responsible for geographic information updates.

4.2 Functional realization

4.2.1 Change-detection app for professional surveying teams

A change-detection app has been developed to support professional surveying teams conducting with field inspection and verification tasks, enabling paperless operations for routine inspections and special task verifications. The app consists of an internet-based field verification tool and a browser-based management system:

(1) Internet-based Field Verification Software

This software allows intermediate administrators to view, assign, and manage verification tasks and inspection personnel. Field surveyors can collect and submit on-site data, such as photos and edits. The main functions include personnel management, task management, data editing, and map management.

(2) Browser-based Management System

This system allows senior administrators to audit field inspection personnel, adjust personnel information, allocate tasks, compile workload statistics, and manage map services. It provides full-process management for field inspections and verifications. The main functions include task management, data statistics, personnel and team management, data management, and map service management.

4.2.2 Change-detection WeChat mini-program for the public

A WeChat mini-program has been developed to facilitate public involvement in issuing verification tasks and reporting change cases. It includes a mobile version for the public and a backend management system for administrators. The mobile version enables on-site operations for the public, while the backend system supports task management, reward management, and result organization.

(1) WeChat Mini-Program Mobile End

In a crowdsourcing model, users can actively identify and report changes by participating in tasks. The main functions include comprehensive map display, change case reporting, survey task issuance, and message management.

(2) WeChat Mini-Program Backend Management System

This system enables administrators to review registered users, manage tasks, compile workload statistics, and oversee map services, providing full-process management for change detection in a crowdsourcing model. The main functions include user information management, update discovery and task management, payment processing, data management, user feedback, and map service management.

4.2.3 Change-detection information management system

The change-detection information management system standardizes the classification and hierarchical management of crowdsourced change data, enabling the aggregation, integration, display, statistics, distribution, and feedback of spatiotemporal change information. This ensures the continuous update and maintenance of geographic data.

The system establishes spatiotemporal archives of changes, records the change process, and facilitates spatiotemporal backtracking. Different types of change information are overlaid and analyzed on the basis of spatial and temporal attributes, distinguishing various levels of map features to facilitate update control.

5. Discussion

5.1 Application in Beijing basic surveying and mapping updates

Through multiple surveys, the content requirements for basic surveying and mapping updates were clarified, leading to the establishment of a standard for automatic change-detection samples using remote sensing imagery, specifically tailored to basic surveying and mapping needs. This standard incorporates business information from the change-detection platform, including the full-process verification of buildings, demolition of illegal constructions, and satellite monitoring for violations.

The implementation of the change detection app and WeChat mini-program has significantly enhanced the efficiency of manual field inspections, transforming the original manual "push-scan" method into a more dynamic and targeted approach. This shift effectively addressed field inspection challenges during the pandemic, resulting in a practical usage rate of 75% for the change-detection results. Unused portions mainly involved large construction areas, where the data provided essential guidance for annual change rate statistics related to surveying tasks.

The detected regional changes were used to support topographic map update projects, with change spots closely aligning with manual work areas, as shown in Fig. 5. There was also potential for classification improvements in some areas. This approach considerably reduced the workload of manual field inspections, providing effective support for overall project scheduling, personnel deployment, and optimization of production processes. The efficiency of change detection improved more than tenfold compared with the previous manual approach.

Previously, manual inspections could cover only 1 square kilometer per person per day, taking approximately two months to complete one survey area. By using change-detection results, the task duration was reduced to about two weeks, allowing changes to be detected through in-house operations alone. Practical applications demonstrated that the change-detection results met the requirements for updating 1:500-scale topographic maps. Furthermore, this change-detection service has supported basic surveying and mapping updates continuously for five years from 2020 to 2024.

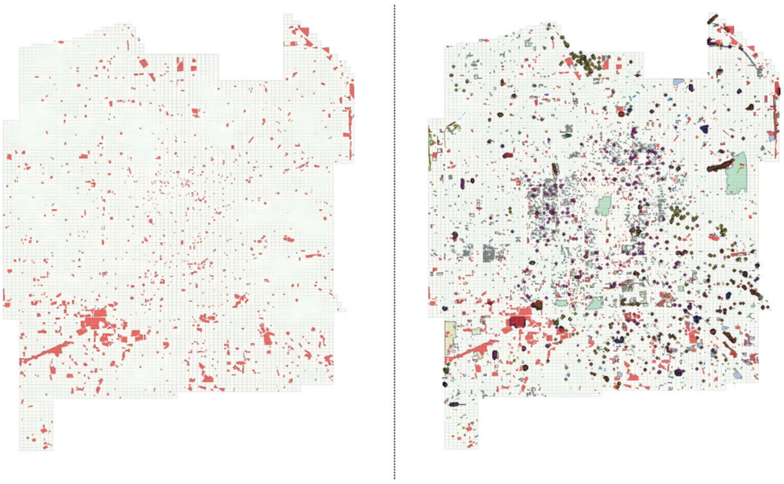

Fig. 5. (Color online) Change-discovery results and practical application.

5.2 Application in land change survey

The primary goal of the land change survey is to assess annual land use changes across the city, referring to the previous year's survey results and using the latest remote sensing imagery, in compliance with national requirements and considering local conditions. Extracting change spots has traditionally been a labor-intensive manual task. By utilizing the change-detection platform, annual citywide land use change spots can be automatically identified, significantly improving the efficiency of this process. Additionally, the automatically detected results can serve to validate the manually extracted outcomes.

6. Conclusions

Traditional methods for updating geographic information data involve long cycles and a large amount of manual work, making it challenging to maintain the data's timeliness and limiting its utility and scope. Timely updates require rapid change detection. With the development of aerial and satellite sensors, as well as Internet and social sensing technologies, rapid change detection becomes possible. In this study, we developed a comprehensive change-detection platform, enabling multichannel change detection and the aggregation, display, and distribution of crowdsourced information. The crowdsourced change-information collection tools facilitated paperless field inspections, improving inspection efficiency and utilizing a crowdsourcing model for geographic information element updates. This contributed to the shift from a "push-scan" to a "change-discovery-driven" method for updating basic surveying topographic maps and demonstrated its applicability in land change surveys. Through the change-detection platform, changes were identified in a timely manner, achieving a change-discovery-driven approach for geographic information updates. This approach effectively supports the production of the most current and accurate geographic information data. In the future, research would be conducted on the fusion of information on changes in different channels.

References

1 M. Dong, H. P. Chen, and Y. N. Zhen: Beijing Surv. Map. **32** (2018) 15. https://doi.org/10.19580/j.cnki.1007-3000.2018.01.004
2 M. M. Duan, H. T. Li, M. J. Peng, S. Wang, and T. Chen: Urban Geotech. Invest. & Surv. **05** (2021) 35. https://doi.org/10.3969/j.issn.1672-8262.2021.05.007
3 X. X. Wang and Z. P. Zou: CSEM. **33** (2017) 4. https://CNKI:SUN:CHBC.0.2017-04-006
4 S. Y. Li, J. Gong, and J. Yang: Bull. of Surv. and Mapp. 01(2021)130. https://doi.org/10.13474/j.cnki.11-2246.2021.0025
5 P. F. Fan: J. Geomatics. **42** (2017) 6. https://doi.org/10.14188/j.2095-6045.2016117
6 W. Jin and Z. Y. Yan: Geomatics Spatial Inf. Technol. **44** (2021) 106. https://xueshu.baidu.com/usercenter/paper/show?paperid=1q430j10qm7y0gq0yq1q0vd0qu398415&site=xueshu_se
7 Z. Y. Wu, X. Pei, and T. M. Wang: Geomatics Spatial Inf. Technol. **47** (2024) 221. https://xueshu.baidu.com/usercenter/paper/show?paperid=1e570gf0yj6d0t40q07x0cp02u249407
8 S. R. Chen, P. P. Shen, and Y. Bao: Bull. of Surv. Mapp. **01** (2021) 90. https://doi.org/10.13474/j.cnki.11-2246.2021.0016
9 Y. B. Ye: Western Resources, **4** (2018) 147. https://doi.org/10.16631/j.cnki.cn15-1331/p.2018.03.069
10 D. Q. Zhang, S. L. Liu, J. B. Pan, and W. Wang: Geomatics spatial Inf. Technol. **42** (2019) 8. https://doi.org/10.3969/j.issn.1672-5867.2019.08.008
11 L. Lin, B. L. Tan, and L. Tan: CSEM. **037** (2021) 42. https://doi.org/10.20007/j.cnki.61-1275/p.2021.01.010
12 D. Liu, L. Fang, and J. Jiang: Geomatics Spatial Inf. Technol. **42** (2019) 100. https://wenku.baidu.com/view/55262898e209581b6bd97f19227916888486b985?fr=xueshu_top&_wkts_=1737526552748
13 J. F. Zhu and L. Y. Su: Geomatics World **26** (2019) 1. https://doi.org/10.3969/j.issn.1672-1586.2019.01.018
14 X. G. Zeng, F. Ren, Q. Y. Du, and L. J. Tang: Geomatics Inf. Sci. Wuhan Univ. **38** (2013) 950..https://doi.org/10.13203/j.whugis2013.08.014
15 S. Ying, J. Yang, K. Wang, L. P. Zhu, P. C. Li, and Z. Li: J. Geomatics. **41** (2016) 62. https://doi.org/10.14188/j.2095-6045.2016.02.015
16 J. F. Cao: Research on land cover mass contract reporting method based on mobile terminal (Shandong Normal University, Shandong, 2017).
17 B. Yang, Y. Mao, J. Chen, J. Q. Liu, J. Chen, and K. Yan: Natl. Remote Sens. Bull. **27** (2023) 1988. https://doi.org/10.11834/jrs.20222156
18 C. Q. He and Y. J. Qian: China Dev. **24** (2024) 89. https://doi.org/10.15885/j.cnki.cn11-4683/z.2024.02.007

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