Research on Dynamic Updating Technology of Digital Maps for Mobile Communications Based on Multi source Remote Sensing Images

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Abstract

With the rapid development of 5G networks in China, mobile communication network simulation technology has gradually become a widely studied direction in the academic and application fields. This study focuses on three-dimensional digital geographic information data for mobile communication, including a large amount of geographic information data that significantly affects the propagation of mobile communication radio waves, such as terrain height and ground use types. These data play a crucial role in coverage prediction, interference analysis, and frequency planning in various telecommunications planning software. This article starts from the perspective of mobile communication network management, and combines typical large-scale terrain data production practice projects for mobile communication to deeply study the process and system function design of combining geographic information systems with multi-source remote sensing data in mobile communication network monitoring and management. On this basis, this study designed and implemented a dynamic updated terrain database for mobile communication. This database can update geographic information data in real-time, ensuring the timeliness and accuracy of the data. At the same time, by optimizing the database structure and query algorithms, the speed and efficiency of data processing have been improved, providing efficient and reliable solutions for coverage prediction, optimization analysis, and planning management of large-scale mobile communication networks.In summary, dynamic updating database of three-dimensional digital geographic information has important application value in mobile communication network simulation technology. Through in-depth research and application of this database, the performance and service quality of mobile communication networks can be effectively improved, laying a solid foundation for future communication technology development.

1. Introduction

In recent years, China's mobile communication industry has experienced rapid development, especially with the rapid deployment and popularization of 5G networks. As the world's largest mobile communication market, China has made significant achievements in the construction of 5G networks, not only promoting the upgrading of the domestic communication industry, but also contributing an important force to the development of global 5G technology. In 2022, against the background of the continuing epidemic and increasing global economic uncertainty, China's 5G development bucked the trend and played an active role in stabilizing investment and growth, becoming a veritable "leader" of new infrastructure. According to the data of the Ministry of Industry and Information Technology of China, by the end of November 2022, the total number of 5G base stations in China has reached 2.287 million, accounting for more than 60% of the total number of 5G base stations in the world. Achieve the 5G network coverage of all prefectures, cities and counties, and 97.7% of towns and townships in the country. Achieve the 5G network coverage of developed administrative villages in developed areas such as Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta [1]. Compared with 4G, 5G has higher signal frequency and faster attenuation, and each base station can cover a relatively smaller area. Therefore, the continuous coverage of 5G network is also more difficult, and more base stations are required per unit area [2-4].

As an indispensable means of scheme evaluation in the process of network construction, mobile communication network simulation technology has been paid more and more attention and applied [5]. The rise of this technology not only highlights its important role in network planning, optimization, and upgrading, but also highlights its key role in promoting the continuous progress of mobile communication technology. In complex network construction environments, simulation technology can provide a virtual experimental platform, allowing engineers to simulate various possible network scenarios and evaluate the performance of different solutions, providing strong decision support for actual construction. In mobile communication network simulation technology, the application of three-dimensional digital maps is even more indispensable. The three-dimensional digital map of mobile communication used in mobile communication network simulation technology specifically includes a large amount of geographic information data that has an impact on mobile communication radio wave propagation, such as terrain height, ground use types and other categories [6]. It is an important basic data for coverage prediction, interference analysis and frequency planning of various telecom planning software [7]. Any decision-making and planning are carried out on the basis of data. In the planning and optimization of telecom network, all kinds of geographic information data are essential, including

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electronic map, elevation map and base station information [8]. However, although 3D digital maps play such an important role in simulation technology, they face many challenges in practical applications. On the one hand, due to insufficient understanding of mobile communication technology by map suppliers, the 3D digital terrain data they provide often cannot meet the requirements of simulation software, resulting in data being unusable or having errors. On the other hand, mobile communication practitioners may also be unable to correctly interpret and apply this data due to a lack of corresponding geographic information knowledge, resulting in misuse. Moreover, at present, the corresponding industry standards have not been released for the communication network planning map, and the implementation of relevant projects is mostly in accordance with the unilateral requirements put forward by the communication operators [9].

2. Technology roadmap

2.1 Technology roadmap

This study carefully designs a detailed technical roadmap with mobile communication network management as the core perspective, aiming to build an efficient database that can integrate geographic information systems and multi-source remote sensing data in real-time, and achieve dynamic updates. This design not only considers the urgent needs of current mobile communication network management, but also focuses on future technological development trends, striving to improve the intelligence and refinement level of management while ensuring stable network operation. In the process of constructing this technology roadmap, we fully drew on the rich experience of multiple digital terrain map production practice projects that the project team had previously encountered. These projects not only provided us with a deeper understanding of the integration application of geographic information systems and remote sensing data, but also provided us with valuable practical experience and data support. By integrating these experiences into practical application scenarios, we are able to conduct more in-depth and detailed research on the process and system function design of mobile communication network monitoring and management. In the research process, we focus on combining theory with practice. Through sorting and analyzing the existing mobile communication network management processes, we identify pain points and difficulties, and then propose targeted optimization solutions. At the same time, we have also designed an efficient data integration and update mechanism based on the characteristics of multi-source remote sensing data to ensure the real-time and accuracy of the database. In the end, we built a powerful and easily scalable mobile communication network management database system, which not only enables real-time monitoring and management of mobile communication networks, but also provides decision support and data analysis services for relevant departments. This achievement has not only made positive contributions to the development of mobile communication network management, but also laid a solid foundation for future technological applications and innovation. The technical roadmap is shown in Figure 1.

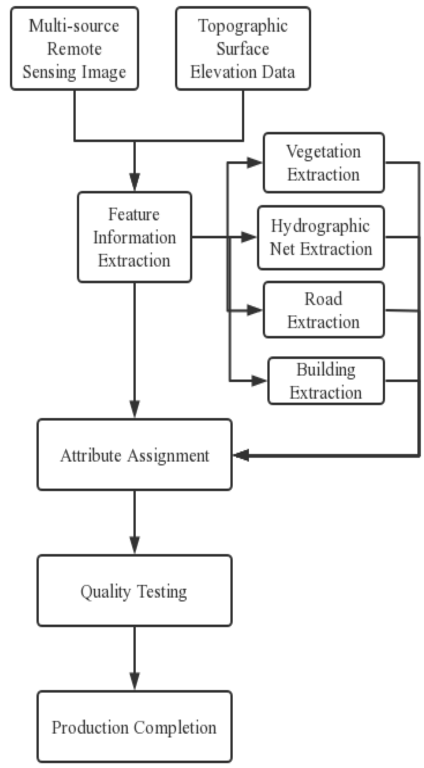

Figure 1. Technical roadmap.

Combined with the various digital terrain map production practice projects that the project team has previously encountered, this paper studied the process and system function design of combining geographic information systems with multi-source remote sensing data in mobile communication network monitoring and management from the perspective of mobile communication network management. It also designed dynamic updated data production experiments for mobile communication using practical applications, The basic idea is to integrate and utilize digital geographic information data for mobile communication, as well as terrain and surface elevation data such as DSM, DHM, and DEM, which have been completed in previous years. Then, based on preprocessed and fused multiple remote sensing images, production experiments are carried out on key technical nodes of surface coverage map production from multiple aspects such as administrative divisions, roads, railways, water systems, and buildings. Finally, the construction of a dynamic update database was completed by combining the massive vector change pattern data formed by image processing analysis with the surface coverage elevation information accumulated from previous projects. This database achieves dynamic updates of geographic information data by integrating multi-source remote sensing images. We particularly emphasize the accuracy of the data and its matching with the actual communication network situation, ensuring that the database can provide accurate and real-time support for the monitoring and management of mobile communication networks.

3. Data structure design and construction practice

The digital terrain data format of mobile communication is a key component of mobile communication network planning and management, providing an important geographic information foundation for network optimization, coverage analysis, and fault localization. Among them, data formats such as EET, Planet, Cellplanner, and Netplan are widely adopted in the industry, providing standardization and compatibility for mobile communication applications at different levels [10-11]. Taking the widely used Planet format as an example, this data format can efficiently integrate and display various thematic combination elements required for wireless network planning maps. These elements include altitude data, which reflects the ups and downs of the ground and is crucial for wireless signal propagation and coverage prediction; Clutter data, which describes different features of the ground, such as vegetation, buildings, etc., and has a direct impact on the attenuation and reflection of wireless signals; Vector data, used to represent linear features such as roads and railways, is of great significance for path planning and signal coverage analysis; Building distribution data, which records the location, height, and shape of buildings in detail, is essential information in wireless network planning; Place name landmark data (Text) provides text information such as place names and street names, making it easy to locate and navigate.

In Planet format, data is generally classified according to different resolutions, such as 5 meters, 20 meters, and 50 meters. This resolution division is to meet the network planning needs of different regions. For example, in densely populated urban areas, due to dense buildings and complex terrain, higher resolution data (such as 5 meters) is required to ensure the accuracy of network coverage; In suburban or rural areas, due to relatively flat terrain and sparse distribution of buildings, lower resolution data (such as 20 or 50 meters) can be used to reduce costs and improve processing efficiency.

Ground features are also classified in detail in the Planet format, mainly including four categories: transportation, water systems, green spaces, and buildings. These classifications help to better understand and analyze the wireless propagation environment on the ground, providing more accurate data support for wireless network planning. For example, transportation and water systems have a significant impact on signal propagation and require special attention during planning; Green spaces and buildings have varying degrees of impact on signal attenuation and reflection, requiring targeted analysis and processing.

In terms of data generation, multi temporal remote sensing image difference analysis is an effective technical means. By comparing remote sensing images at different time points, ground change information can be identified, such as new buildings, road renovations, etc. These changes are of great significance for the updating and maintenance of wireless network planning. By utilizing multi temporal remote sensing image difference analysis technology, updated digital terrain data can be automatically generated to ensure real-time and accurate data. The digital terrain data format and content of mobile communication play an important role in wireless network planning. By utilizing these formats and contents, we can better understand and analyze the wireless propagation environment on the ground, providing strong data support for network planning and optimization. At the same time, the application of multi temporal remote sensing image difference analysis technology also provides an effective technical means for the automatic generation and updating of data. [12].

In order to ensure the accuracy and real-time performance of geographic information data in mobile communication network monitoring and management, we have designed and implemented a dynamically updated terrain database for mobile communication. The system is based on multi-source remote sensing image data and ground survey data, combined with GIS technology and database technology, to achieve automatic updating and maintenance of large-scale terrain data for mobile communication.

3.1 System architecture design

The system adopts a three-layer client/server structure. The client includes a geographic information collection client, a data maintenance client, and a data query client. The server includes a data management server and a data update server. The geographic information collection client is used to collect real-time ground information and remote sensing image data, the data maintenance client is used to perform quality control, data processing, and data update on the collected data, and the data query client is used to query and obtain terrain data from the server. The data management server is responsible for storing and managing data, and the data update server is responsible for updating existing data based on newly collected data.

3.2 Database design

In order to support dynamic updating of terrain data, we have adopted relational database technology and designed corresponding data table structures [13]. The data table structure is shown in Table 1.

Field Name	**Field Type**	**Description**
id	int	Data unique identifier
longitude	double	Longitude to which the data belongs
latitude	double	Latitude of data
elevation	double	Elevation to which the data belongs
terrain_type	int	Terrain type to which the data belongs
source_type	int	Type of data source, includ-ing remote sensing image data and ground measurement data
source_name	varchar(50)	Data source name
create_time	datetime	Data creation time
update_time	datetime	Data update time, used to record the latest update time

Table 1. Data table structure.

To support dynamic updates of data, the update time field is added to the database table design. When new data arrives, the system will match and update the existing data based on the longitude, latitude, and elevation information of the data, while updating the update time of the data. This can ensure the real-time and accuracy of data.

In addition, the system has also designed some auxiliary tables for storing type information and data source information of terrain data. These tables can help the system classify and manage data.

3.3 System implementation

In order to achieve dynamic update of data, the system proposes to use a combination of multi-source remote sensing image data and ground survey data to comprehensively and finely identify and classify terrain using remote sensing image data, and to accurately correct elevation data in combination with ground survey data.The system implementation process is as follows:

1) Data collection: Use the geographic information collection client to collect real-time ground information and remote sensing image data.
2) Data processing: Classify, process, and quality control the collected data, including terrain type classification, elevation correction, and data quality inspection.
3) Data storage: Store the processed data in the data management server while updating the update time of the data.
4) Data update: Match and update the newly collected data and existing data, store the updated data in the data management server, and update the update time of the data.
5) Data query: Use the data query client to query and obtain terrain data from the data management server.

Among the four ground features of traffic, water system, green space and buildings. Taking traffic data as an example, in production practice, it is collected and classified according to the road level, function and width according to the vector category to form the road network layer classification data [14]. The main road types are defined as follows: expressways refer to highways with more than 4 lanes, two-way separated driving, fully controlled entrances and exits, and all use grade separation, which are generally distributed outside the urban area. First-class highway refers to the highway for vehicles to drive in different directions and lanes, with partial access control and partial interchange. It mainly connects important political and economic centers and leads to key industrial and mining areas. It is a national trunk highway. Second-class highway refers to the trunk highway connecting political and economic centers or large industrial and mining areas, or the suburban highway with busy transportation, which can generally adapt to the driving of various vehicles. Third-class highway refers to the general trunk highway and branch highway connecting third-class administrative regions and administrative regions below third-class, which can usually adapt to various vehicles. Urban trunk roads refer to the fast transportation services that mainly connect the main areas of the urban area, the urban area and the main suburban areas, satellite towns, main external roads, etc., and provide large traffic volume and long distance. Trunk roads with a general width of more than 15m, more than 4 motor lanes and a maximum speed of no less than 60km / h. Urban secondary trunk road refers to the trunk road connecting the main districts of the city and shunting the first-class roads of the city, mainly with traffic functions. A road with a general width of 10-15m, four motor lanes and a maximum speed of no more than 60km / h. Urban branch roads refer to roads that combine with urban primary roads and urban secondary roads to form a road network, which plays the role of distributing traffic and has service functions. Including small roads, alleys and main roads of the community. And the roads that cannot be accessed by motor vehicles outside the above areas, such as markets, pedestrian streets, etc. Airport runway refers to the runway and carriageway built in the airport for aircraft take-off and landing. Other roads refer to roads other than those defined above. The corresponding table of road type name, classification code and road type in China is shown in Table 2 below.

Code	**Road type**		**Road type (China)**
10	Intercity highway	Expressway	Expressway
11		First-class highway	National highway
12		Second-class highway	Provincial highway
13		Third-class highway	Prefectural highway/Country highway
20	Urban highway	Urban trunk road	Urban first-class road
21		Urban secondary trunk road	Urban second-class road
22		Urban branch highway	Urban third-class road
31	Other roads	Airport runway	Airport runway
39		Other roads	Others

Table 2. Road type classification.

3.4 Demonstration area production test

Taking the three-dimensional digital map data of network planning optimization for 21 central urban areas in Guangdong Province of a certain mobile communication company as an example, the project team fully utilized the existing geographic information data results of the surveying and mapping department, and combined them with the ArcGIS software platform to deeply carry out the production practice of the terrain data result database. This practice not only improves the accuracy of network planning, but also provides strong data support for subsequent simulation analysis and optimization management. In the process of data production, the project team first preprocessed the original geographic information data provided by a surveying and mapping institution, including data cleaning, format conversion, and coordinate unification.

Subsequently, utilizing the powerful capabilities of the ArcGIS software platform, further analysis and processing were carried out on the preprocessed data, extracting terrain and geomorphic information closely related to network planning.

As the capital city of Guangdong Province, the importance of network planning in Guangzhou is self-evident. Therefore, the project team conducted a more detailed data integration analysis on the key areas of Guangzhou after data processing. As shown in Figure 2, the local vector results of Guangzhou display detailed terrain and geomorphic information of the region, including the distribution and characteristics of roads, buildings, water systems, and other elements. These vector data not only provide accurate spatial references for network planning, but also provide rich data sources for subsequent simulation analysis.

After completing the production of the terrain data achievement database, the project team seamlessly integrated it into the network planning and management platform of the communication company. After later testing and use, the digital terrain data results have shown good performance on the platform. On the one hand, it realizes visual management and analysis of network planning simulation, enabling planners to intuitively understand network coverage and signal propagation characteristics; On the other hand, it also provides strong data support for network optimization, helping companies accurately locate problem areas and develop corresponding optimization measures. This production practice not only indirectly verifies the accuracy and efficiency of mobile communication companies using dynamic updates of geographic information databases for mobile communication network planning, but also provides useful reference and inspiration for how geographic information data can assist the sustainable development of the communication industry. In the future, with the continuous advancement of technology and the expansion of application scenarios, we believe that digital terrain data will play a greater role in more fields.

Figure 2. Guangzhou partial vector terrain data

The geographic information data involved in the mobile communication industry is characterized by a huge amount of data and is closely related to the surface coverage [15]. Mobile communication optimization analysis mainly includes field strength prediction, frequency planning and voice quality analysis, which are inseparable from the terrain data of the planned area. By establishing the digital map database for mobile communication, these telecom data can be analyzed intuitively on the map, so that the staff can completely get rid of the boring data and text reports, and get the strong support of macro decision-making. The continuous development of remote sensing and geographic information system not only becomes the premise and basis of wireless network coverage prediction, but also provides an effective way for wireless network planning and optimization design.

4. Summary

Compared with the traditional manual operation and empirical judgment, the planning and optimization of mobile communication network using GIS technology shows great advantages. The strong spatial data analysis characteristics of geographic information technology in geographical environment provide effective technical means for mobile communication network coverage prediction, and realize efficient, fast, scientific and accurate mobile communication network planning and optimization design. Therefore, it has good engineering application value. With the help of the results of mobile communication thematic terrain data, the visualization ability and spatial analysis function of GIS, combined with the wireless communication statistical model, the mobile communication network planning and Optimization Based on geographic information technology can accurately predict the wireless network coverage, find the communication blind area, optimize the parameter setting, plan the community classification and base station location, Optimize the allocation of wireless frequency points and wired resources, and provide auxiliary reference and decision analysis for the planning and optimization design of mobile communication network, so as to scientifically and effectively support the planning and management of mobile communication network and further improve the mobile communication network. Through the combination of multi-source remote sensing data and GIS technology, this paper designs and implements a dynamically updated terrain database for mobile communication. Aiming at the better management effect of the current rich surface coverage information, the database enriches the intelligent planning and analysis of mobile communication related departments, improves the work efficiency of management departments, and also provides an important part for the construction of smart 5G and smart city.

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