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Development of Geographic Information System for Mineral Resources in Highway Engineering

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Abstract: Geographic Information System (GIS) is a specific and very important spatial information system. Composed of computer systems, geographic data, and users, various geographic information is generated and output through the integration, storage, retrieval, operation, and analysis of geographic data. This provides new knowledge for land use, resource management, environmental monitoring, transportation, economic construction, urban planning, and government administrative management, serving engineering design, planning, and management decision-making. This article applies geographic information theory to the management of road aggregates and establishes a geographic information system for road materials resources in the Rizhao area under the GIS platform. The development of this system mainly consists of two modules: one is the road materials resource database, and the other is the road materials resource geographic information management system. The road material resource management system is developed and established based on GIS, which stores and analyzes a large amount of scattered road material resource information such as resource attributes, technical indicators, economic parameters, etc. through computers. This not only avoids a lot of repetitive work, but also provides important material foundation and technical support for improving the scientific and standardized level of decision-making and management work. This system achieves the unification and sharing of various maps and data information, which can efficiently utilize various basic information. Based on the search, analysis, and other processing results of the distribution and demand of road land resources, statistical analysis, decision-making, and management work can be carried out.

1. Introduction

The distribution of road land resources has significant regional natural geographical and environmental characteristics, and is closely related to the planning and construction of highways [1] . Adopting traditional survey methods not only wastes a large amount of manpower, material resources, and financial resources, but also has high repetitive workload, poor timeliness, and slow resource information updates [2,3]. With the rapid development of China's highway transportation industry and economic society, scientific, economic, and environmentally friendly highway construction and maintenance have gradually become a new development trend [4, 5]. The development and establishment of a road material resource information management system based on GIS will undoubtedly provide convenient information services and technical support for highway planning and construction, as well as the development and utilization of road material resources.

2. Overall Design of the System

2.1. System Design Objectives

The overall goal of the development of this system is to consolidate the information of land resources for the surrounding roads in Rizhao onto a single platform for better analysis, management, planning, and utilization [6]. The systematic research, design and development will be closely combined with the distribution, development and utilization of road land materials (including sand, stone, mineral powder, soil, water, lime, cement, etc.) in the region [7]. The system not only has the functions of analyzing the properties, reserves, and utilization status of road materials in various regions, but also fully utilizes the powerful spatial graphic data and attribute data management functions of GIS to achieve effective management of road material resources, as shown in the following figure.

The road land resource information system developed based on GIS will systemically sort out and classify a large number of scattered road land materials, such as stock yard distribution, storage capacity, mining output, transportation conditions, main technical characteristics and remarks, establish stock yard attribute database, geographic graphics database, technical and economic parameter database, etc., and further realize the association between road land material data information and geographic data information, And the organic combination of road land material data information with highway network distribution and construction information.

According to the design objectives of this system, the development of the system will have the following characteristics:

(1) It is the first time to conduct a comprehensive survey of the road land resources (coarse and fine aggregates) in Rizhao area, and conduct a detailed survey of the quarries being mined, including the location of the quarries, storage capacity, mining output, etc., which provides a large amount of detailed basic data support for the realization of the system design goals.

(2) The system provides web services to achieve data sharing. The updated data of the material yard can be uploaded to the server in a timely manner, achieving dynamic updates of the data.

(3) Using advanced technical framework - based on C #+ArcGIS Engine+ArcSDE development, ArcGISEngine has all the advantages of ArcGIS platform, such as progressiveness, scalability and compatibility of the development platform. ArcSDE can manage massive amounts of geographic basic data. This system can reorganize and integrate GIS functions, making it a user-friendly and flexible geographic information system for land resources.

(4) The system database is more comprehensive, including data on railway routes and river basins. On this basis, the system has developed the shortest path analysis function, which analyzes the shortest path and freight cost of the nearest material yard when transporting road materials resources to the destination through four different transportation methods: highway, non highway, railway transportation, and water transportation, and conducts a comprehensive comparison and selection of plans to determine the most economical and reasonable transportation plan. Compared with other GIS, this system has developed Buffer analysis and distance measurement functions.

(5) The system relies on data sharing function and asphalt mixture traceability marking technology to compare the application effect of Production set produced by various manufacturers in actual roads.

2.2. System Design Principles

According to the design idea of software engineering, the system shall meet the design principles of reliability, safety, fault tolerance, adaptability, scalability, practicality, progressiveness and operability.

(1) Reliability refers to ensuring the long-term stable operation of the system. Both hardware and software design and information resource systems should meet the requirements of reliability.

(2) Security refers to having necessary security protection and confidentiality measures to prevent computer crimes and viruses from invading the system.

(3) Fault tolerance refers to the ability to prompt or automatically eliminate inappropriate user actions, in order to improve the system's fault tolerance and anti-interference ability.

(4) Adaptability refers to having strong adaptability to continuously developing and improving statistical reports, data materials, and indicator systems.

(5) Scalability refers to leaving sufficient room for further expansion and upgrading of system hardware and software in the future, to avoid system failure due to expansion, upgrading or modification of hardware and software.

(6) Practicality means that the technology used must be mature and practical, so that the necessary development functions of the system can be achieved and the expected social and economic benefits can be achieved.

(7) Progressiveness means that on the basis of practicality, the system has high technical performance by absorbing the experience of similar systems at home and abroad and adopting advanced software development technology platforms at home and abroad.

(8) Ease of operation, which is based on the principle of facing end customers and establishing a friendly user interface, enables users to operate the system simply, intuitively, and easily, even without the presence of database experts or GIS professionals.

3. Module Design of the System

The design of this system follows the principles of modularization, reliability, practicality, openness, maintainability, and humanization for development [8]. The system adopts modular design and is divided into relatively independent functional modules according to different business functions [9]. The main functional modules are: Home screen module, data acquisition module, data editing module, query and analysis module, report generation sub module, graph generation sub module, data backup module and data output module.

(1) Home screen module

The functions of the Home screen module mainly include map browsing and layer display. Through the map index area and map operation tools in the system, it is possible to zoom in, zoom out, and roam the main view area map, and browse the electronic map of the system. By operating the layer control area, it is possible to selectively display the system layers.

(2) Data collection module

The data collection module of this system includes material yard data collection and basic geographic data collection. Material yard data collection involves processing and inputting data related to the newly built material yard into a spatial database. There are two methods for data collection: direct import and manual input.

The process of collecting basic geographic data includes receiving data, analyzing and comparing the content and definition of the data, transmitting the data to a preprocessing server, conducting initial data quality and integrity checks, and generating corresponding quality inspection reports, correcting possible errors and issues, uploading the data to the database, establishing AL topology relationships, establishing indexes, conducting quality inspections, and establishing a metabase. (3)

Data editing module.

Due to the inevitable occurrence of errors during the data collection and input process, necessary editing and processing should be carried out after the data collection and input are completed to ensure the accuracy of the data. The data editing module implements functions such as adding power, modifying, and deleting data.

(4) Query analysis module

The query and analysis module is the main functional module of this system, including basic attribute query function, buffer query function, shortest path analysis function, and statistical query function.

1) Basic attribute query function. Based on user needs, select the data of the interested material yard and view the basic properties of the material yard.

2) Buffer query function. Query the distribution and basic information of material yards in a spatial area or buffer zone based on their spatial location.

3) Shortest path analysis function. Based on certain conditions, search for the nearest material yard to the target point and display the shortest path for transportation of land resources.

4) Statistical query function. Based on the geographical location, daily production, storage capacity, and material properties of the material yard, comprehensive queries are conducted according to conditions.

(5) Generate Report Module

Provide reports to users by extracting existing report data or querying and generating report data based on user-defined combination conditions.

(6) Generate Graphics Module

The functionality of this module has been integrated into other functional modules.

(7) Data backup module

The function of the data backup module is to backup data based on the given backup time period and backup method. The data backup module has two methods: static backup and dynamic backup. It can be backed up through static backup, such as optical or tape backup, or through dynamic backup, such as hard disk mirror backup or dual machine backup.

(8) Data output module

Users are the primary users of output information. Therefore, when designing output content, the first step is to determine the user's requirements for using information, including usage purpose, output speed, frequency, quantity, security requirements, etc.

4. System Database Design

As an important component of the road material resource geographic information system, the database must be designed to construct an ordered and reflective dataset of the actual survey road material data [10]. The database of this system mainly includes spatial positioning data and geographic attribute data, and organically linking the two and organizing and managing the data is an important part of the database design work. The reasonable selection of database structure design and data organization methods is the basic prerequisite for maintaining the consistency and integrity of spatial data and ensuring the effective operation of the system. This system is implemented using a SQL Server database.

4.1. Data Organization Description

The spatial data structure design of the system includes encoding and organizing spatial data. The purpose of spatial data encoding is to convert map or graphic data, geographic data, and statistical data of materials into a certain data structure, and to achieve spatial data structure design through computer storage and processing. The spatial data structures supported by GIS software mainly include raster data structures and vector data structures.

The spatial data structure of this system adopts a vector data structure. The system data sources include map or graphic data, geographic data, and statistical data of road land resources. According to the basic characteristics of data, it mainly includes graphic data and attribute data. These vector data are stored in the SQL Server database.

(1) Vector data

Vector data is data stored in a vector format, consisting of a scalar representing position and a vector representing direction. Vector data structure mainly expresses the geometric position of spatial objects by recording their coordinates and spatial relationships. By recording entity coordinates and their relationships, geographical entities such as points, lines, polygons, etc. are represented as accurately as possible. As the most common graphic data structure, vector data has the greatest advantage of not distorting whether it is enlarged, reduced, or rotated. Moreover, its coordinate space is assumed to be continuous and does not require quantization processing. Compared to raster data structures, it can more accurately determine the physical spatial position.

(2) Basic data

Data is a fundamental component of GIS databases, and GIS platforms must be built on the basis of data. The basic data used in this system includes geographic data, road material resource data, and graphic data.

4.2. GIS Database Establishment

The GIS database of road materials resources includes spatial databases and graphic databases. The geospatial database is organized and stored in a hierarchical manner. In the GIS management system for road land resources, the hierarchical standard for spatial data is used, As shown in Table 1.

Table 1: Layering of spatial data

Layer Categories	Layer Names	Layer Properties
Geographic Data Layer	ProvincialAdministrative division	surface
	Provincialgeological distribution	surface
	Water network	line
	expressway	line
	PlannedExpressway	line
	nationalhighway	line
	ProvinciaIHighway	line
	railway	line
	Tollstation	point
	NatureReserve	point
	Township	point
Road material resource layer	cement	point
	Stonematerial	point
	sand	point
	Mineralfraction	point
	lime	point
	water	point
	Soil	point

4.2.1. Establishment of Geographic Basic Database

The geographic basic database of this system includes the following 13 types of basic data:

Provincial administrative map: Provincial geological distribution map: Water system: Expressway: Planned expressway: National highway: Provincial highway: County highway: Railway: Toll station: Nature reserve: River sand mining area: Township.

The establishment of geographical basic database is based on the above 13 basic data, and its manifestations are geographical data spatial database and Graphics library.

The geographic data spatial database in the GIS system of road land resources mainly includes spatial positioning data and geographic attribute data. It is very important to establish the connection between these two types of data and organize and manage them. The drawing and display of the Graphics library must be supported by other corresponding databases and established on this basis. At the same time, the Graphics library provides users with intuitive and convenient query and display functions through the Spatial query function. The Graphics library of the system consists of provincial Administrative division map, provincial geological distribution map, road network distribution map, etc.

4.2.2. Establishment of a Database for Geomaterial Resource Information

The ground material resource information database is the business data of the system, including cement, stone, sand, mineral powder, lime, water and soil. The ground material resource information database contains all road land material resources, which is the key and core content of material resources. Analyze and summarize the provincial road land resource information collected through the survey. The information database of ground material resources systematically provides the distribution information of road land material resources with the road network and water network as the main line and the Administrative division map as the carrier. Mainly including: material yard name, location, material yard number, material name, storage capacity, daily production capacity, reference price, material property description, transportation conditions, and remarks.

4.2.3. Establishment of Road Network Spatial Database

The establishment of a road network spatial database is mainly aimed at solving the problem of spatial positioning of the distribution of road materials. The spatial data of the system's road network includes four types of road networks: provincial highways, national roads, provincial roads, and county roads. The establishment of a road network spatial database and the topology of the road network provide a basis for determining the transportation path of road land resources.

The road network spatial database is a road network established based on highways, national roads, provincial roads, and county roads. The road network involves attribute information such as two-dimensional coordinates, intersections, ranges, and road names of each section of the road. The road network data establishes the topology of the road network, providing a foundation for the implementation of functions such as shortest path analysis in the system.

5. Conclusions

This article is based on the survey data of the surrounding material sources in Rizhao, using ArcGIS as the operating platform, using SQL Server database, and C #+ArcGIS Engine+ArcSDE to develop and establish a road material resource database with detailed basic information. The "Geographic Information Management System for Road Material Resources" has been developed and completed, and a GIS system for road construction material resources has been established, which integrates scattered and large amounts of road construction material information on one platform, It is beneficial for the government management department to understand and grasp the distribution of road building materials in the decision-making of road material resource extraction and the construction unit's construction organization design, achieving economic and reasonable material selection, and achieving intelligent decision-making of mineral material selection and transportation routes.

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