

## Research Article

# Optimization of Geological and Mineral Exploration by Integrating Remote Sensing Technology and Borehole Database

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Mineral exploration as the basis for the development of important mineral resources and economic construction, improving the efficiency of geological exploration is conducive to improving the quality of mineral resources. In this paper, the study of modern mineral resources exploration and utilization methods, drawing on the problems in geological exploration work, discusses effective countermeasures to improve and optimize the level of geological exploration from the perspectives of remote sensing technology and borehole database, etc., with a view to improving the efficiency of geological exploration and mineral search technology, so that energy production can achieve sustainable development and be free from the constraints of increasingly difficult mineral resources development. Based on remote sensing technology, GIS is a system derived on the basis of advanced science and technology and information technology, and its application to geological and mineral exploration can help relevant personnel to have foresight to understand the development of geological exploration and provide detailed data support for optimizing geological exploration work. Coalfield geological exploration arranges a large number of boreholes to find out the thickness of coal seams in the exploration area, the distribution pattern of coal seams and the spacing of coal seams, the characteristics of the top and bottom of coal seams, and the characteristics of coal quality. In the coal mining excavation, the technical personnel need to study the geological data of the borehole in time to design or adjust the excavation plan scientifically and reasonably. By implanting an electronic chip in the drill hole markers completed by drilling, the borehole coordinates, elevation, preservation of the borehole markers, and the website address of the borehole database management system are sent to the users in real time, providing geologists with convenient query services of borehole geological information. This paper proposes a geological and mineral exploration optimization method that integrates remote sensing technology and borehole database, and the relevant experiments prove the effectiveness of the proposed method.

## 1. Introduction

All kinds of human economic activities need to consume a large number of mineral resources, and minerals, as basic energy, have nonrenewable characteristics. Although China has a large seaway area and wide distribution of mineral resources, the total amount of minerals is very limited, and many of them are in deep sea or other areas where mining is difficult, and due to the previous large amount of development, the roughly easy to mine and densely distributed resources are heavily exploited, making the future exploration and mining of mineral resources more difficult [1–3]. The report shows that more than 80% of China's industrial production is based on minerals as the basic energy, if the

future lack of mineral production, will have a huge negative impact on industrial development and then affect the speed of China's economic growth, so it is very important and urgent to improve the level of mineral geological survey and mineral search. The complexity of mineral geology is a common problem faced by my country's mineral exploration and mining. Since many minerals are located in complex natural environments such as hills and deep seas, which have brought many problems to the actual construction, the safety of exploration and construction should also be paid attention to, and higher requirements have also been put forward for the exploration and construction management system of enterprises. And currently some Chinese enterprises in the actual mineral exploration and mining

process, based on the time requirements of exploration work, there are problems such as blindly accelerating the exploration progress, which superficially enhances the exploration progress, but in fact leads to insufficient analysis of regional minerals and other problems, on the one hand, leading to some mineral resources are not discovered, on the other hand, to the actual mineral mining work has laid many safety hazards, but also reduces the accuracy of mineral mining. The optimization method of geological mineral exploration is shown in Figure 1.

Traditional mineral search techniques are difficult to adapt to the needs of deep exploration, so it is necessary to apply technologies related to information digitization, use computers, fuzzy mathematics, other analysis principles, and low data analysis difficulties and improve the efficiency and accuracy of the survey [4–7]. Remote sensing, X-fluorescence, and other technologies have been widely used in foreign mineral geological exploration, the former according to the principle of different distribution of different mineral infrared zones, through the ratio enhancement and other methods to accurately delineate the mineral characteristics, in copper and other metal ore finding has the advantages of precision, nondestructive, etc., but also a better analysis of the underground hidden mineral structure. In the actual mineral geological survey and mineral search, it is generally combined with traditional and modern multifaceted technology to conduct accurate survey from large scale to small scale and from surface to underground to improve the survey accuracy. For example, modern tools such as GPS are used in the geological survey of the project, while traditional methods are used in the topographic survey to achieve the quality requirements of different survey targets while making the work well coordinated [8–11].

In recent years, the combination of GPS technology and modern communication technology makes the method of determining the three-dimensional coordinates of the earth's surface develop from static to dynamic and from data lag processing to real-time positioning and navigation, which greatly expands the breadth and depth of GPS applications and substantially improves the technical accuracy and production and scientific research efficiency, showing great superiority, and with the maturity of the technology and the scope of use, the application of GPS in the construction of digital mine production system is an inevitable trend in the construction of modern coal mines and has a broad market prospect, which will definitely bring huge economic benefits. After the construction of the geological borehole in the coalfield, a solar electronic tracking chip is implanted in the sealed hole mark. The solar electronic tracking chip sends the coordinate position to the drilling space database system through GPS positioning to realize real-time positioning of drilling geological data and transmit dynamic information of drilling positioning [12–15]. Once the borehole markers are lost, moved, destroyed, or have wrong coordinates or large errors, the management will understand the situation and make treatment in time and forecast geological disasters to relevant departments or technicians in advance to prepare safety emergency measures or provide indirect evidence of geological structure movement to scientific researchers.

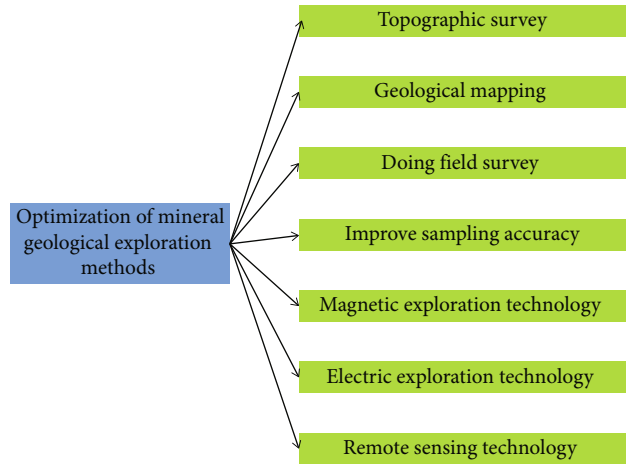


FIGURE 1: Geological mineral exploration optimization methods.

The borehole spatial database system centralizes and unifies the comprehensive coal seam results and coal geochemical analysis results of each borehole to form a borehole network spatial database and publishes and spatially displays borehole geological information in Internet mode, pushes the network domain name (URL) and borehole coordinates to registered users, and provides cell phone navigation service functions. At the same time, QR code is posted on the outside of each borehole logo, so that users can scan the QR code and get the geological data information of a specific borehole in time. This management mode provides a convenient way to obtain geological data of boreholes for coalfield exploration and development and also provides an innovative solution to integrate geological data of boreholes, share geological research results, and promote geological exploration modernization in China [16, 17].

## 2. Related Work

*2.1. Remote Sensing Technology and Geological and Mineral Exploration.* Information technology is developing day by day, and computer network technology is developing day by day and will be widely used in real life. The principle of computer technology and information technology is applied in practice, the development of geological survey instruments tends to be digital and intelligent, and this intelligent mapping technology is continuously applied to various address survey activities, with advanced computer technology and information technology as the support, which makes the efficiency and accuracy of mapping work in geological exploration have been greatly improved [18, 19]. In general, digital mapping remote sensing technology uses instruments to perceive geographic location and topographic conditions while converting these conditions into data and presenting them in concrete data, and the mapping process is “semi-automatic” or does not require human operation at all. This technology will make it much easier to work outdoors in some complex terrain areas, improving efficiency and accuracy at the same time. Digital mapping is also known as digital cartography wherein data is collected, compiled, and formatted into a virtual image. Photogrammetry

is the method of acquiring reliable information relevant to physical objects and their environment using the process of recording and measuring. It also helps in the interpretation of the photographic images and patterns using electromagnetic radiant imaging techniques. Photogrammetry can be divided into underground photography, underwater photography, and aerospace photography according to the different photography equipment and photography distance. Photographs obtained through photography are richer in information and better reflect the details of the objects photographed, which can be used to create more accurate and efficient topographic maps. It is also by the grace of this new technology to transfer the harsh outdoor working environment to indoor, effectively improving the operating environment of the mapping staff, in some high mountains or watery places to better reflect its own advantages and is therefore widely used and widely praised. Photogrammetry also has a variety of processing means, according to different processing techniques can be divided into analog photogrammetry, analysis, digital photogrammetry, and several categories. Among them, analog photogrammetry is the use of some optical instruments and mechanical equipment to simulate photography to achieve the same effect as photogrammetry, while using the established scale model, in order to get the actual data needed; analytical photogrammetry is based on the geometric relationship between the physical location and the imaging position, and then use advanced computers to perform calculations, so as to determine the object reality and record the data into the computer. The data is recorded into the computer and finally plotted. In case of digital measurement of remote sensing technology, the data or information is collected from aircrafts and satellites which are equipped with sensors that are capable of recording electromagnetic (EM) radiation from the objects located on the earth's surface. The recorded radiations by the sensors are placed in an electromagnetic spectrum which includes range of all possible frequencies and wavelength of the radiation. A very small portion of the spectrum is visible by the human eye while the other portions being infrared are not visible by the human eye. Geological surveys require geometric information and geography of the site to be surveyed, which requires the use of certain measurement tools to obtain information about the object to be surveyed and to accurately measure the object. Digital processing technology is used to process the images, and digital photogrammetry is used to establish a database, which is managed to provide geological data for various geological survey projects. Remote sensing technology consists of several important parts: information acquisition system, reception and processing system, survey ground truth system, and information analysis system. Among them, the information acquisition system covers the remote sensing platform and remote sensor [20]. The platform is the carrier of the remote sensor, which plays the function of carrying apparatus, and there are platforms on the ground and in the air. The remote sensor is responsible for collecting and storing the basic information of the measured object or area and then transmitting it to the receiving system. The ground survey system collects information and analyzes data on the ground while

the remote sensor collects relevant information. Digital remote sensing mapping technology is extremely effective in reducing the error in the measurement, with the passage of time, the paper drawings, and data inevitably will be preserved due to moisture and other natural factors and a certain degree of damage, the data content shown in the drawings may appear mutilated or unclear, digital mapping technology can completely eliminate this aspect of the hidden danger, the data stored in the disk, and effectively protect the data. The data will be stored in the disk, effectively protecting the data and thus reducing errors.

Remote sensing technology is indispensable for digital mapping in geological survey, which can collect the ground topographic images to be surveyed, process the images simply, and transmit the data. Generally speaking, the image information obtained by remote sensing technology and the processing of the image as well as the spatial location information of the relevant geographic area are collected with high accuracy and are therefore widely used in surveying work. In addition, remote sensing technology has its own advantages and can present the site geographic environment to the surveyor in a way that is easy to understand and remember, thus improving the surveyor's understanding of the site [20]. At the same time, remote sensing mapping technology can short-term imaging, and you can survey the area within the scope of all the objects converted to images, greatly reducing the time used by the surveyor to compare and analyze the spectrum. For example, in the oil survey, remote sensing technology is used to find hydrocarbons on the surface. The phenomenon caused by the hydrocarbon effect of oil is the change of light reflectivity in the spectral domain, which is expressed as hydrocarbon alteration halo in the satellite imaging. In the upper part of the oil field, due to the increase of various types of iron ore, the reflectivity in the spectrum of 600 to 700 nm becomes larger, and the color is brighter in the imaging; if there are more clay minerals, the reflectivity in the wavelength of about 2200 nm becomes lower, and the color is darker in the imaging. Using remote sensing to find oil fields is the practical application of remote sensing technology in geological survey. In addition, it is also widely used in the geological survey of coal fields. Using remote sensing technology to analyze the horizontal distribution areas of different ground conditions, first analyze and compare the spectral resolution and spatial resolution to determine the data source, then enhance the image processing and synthesize it using Thematic Mapper or Enhanced Thematic Mapper (TM/ETM) which is used to distinguish the vegetation soil moisture and other conditions around the mountain.

*2.2. Borehole Database and Geological and Mineral Exploration.* The construction of geological borehole database is one of the objectives of the information construction work of the main process of Chinese geological survey, which is an urgent need of Chinese geological survey work [21]. At the same time, according to the requirements of standardization of geological survey data, it is also urgent to establish a unified standard geological borehole database covering China and apply GIS technology to manage,

process, analyze, and visualize geological borehole data, which can provide timeliness and efficiency. It can provide standardized and standardized geological borehole data in a timely and efficient manner, realize information exchange and comprehensive analysis application among geological data, greatly improve the technical level of geological borehole data management and service utilization in China, and meet the needs of China's land resources planning, geological survey, geological prospecting, and environmental protection. In the era of big data, the research on the construction of geological borehole database, which is of pioneering significance in China, is important for better keeping the geological borehole data formed with huge national investment, unifying the storage, management, and sharing of geological borehole data resources, breaking the information blockage between various professions, expanding the breadth and depth of geological borehole data utilization, improving the efficiency of geological borehole data utilization, and better utilizing the value of geological borehole data. It has important theoretical and practical significance. The key theoretical, technical, and methodological issues in the construction of geological borehole database, such as standardization and rules of different types of geological borehole data, integration, and convergence of massive data, management, and service, support the construction of database [22].

The construction of geological borehole database in China is a very complex system project. China has organized three pilot projects for the construction of geological borehole database, but none of them has been spread out and completed in China. After analysis, the problems and reasons mainly include three aspects: (1) the construction of geological borehole database involves various kinds of borehole data of different geological work types with many collection contents, and there are some degree of inconsistency and uncertainty in the content and data classification rules of the database integration in China, there is no uniformity in the standardization and standardization of geological borehole data. There are incomplete and unsystematic problems, the organization and management system of geological borehole data and data quality control system are not sound, and the idea of geological borehole database construction is not quite in line with China's national conditions and institutional mechanism. (2) There is a lack of unified management and expression of geological borehole data, attribute data, and analysis model results with a unified geological borehole data model technology in China; there is a lack of an integrated geological borehole data management service system based on GIS technology in China to solve the technical problems of efficient management, convenient service, and visual expression of geological borehole data, which affects the scope of use and utilization efficiency of geological borehole data. This affects the scope of use and efficiency of geological borehole data and is not conducive to the discovery and excavation of deeper contents and knowledge contained in geological borehole data, which affects the quality of macroscopic decision-making. (3) China's geological borehole data are scattered and kept in various grassroots units, with many industry departments

and grassroots units, making it difficult to organize and coordinate, resulting in the integration of geological borehole data kept by various units in China has not been carried out, and the Chinese geological borehole database has not been established. Moreover, due to the many contents of geological borehole data collection, it requires a lot of human and material resources, and the financial support needed is very high, which is also an important reason why the Chinese geological borehole database has not yet been built. In the next step of the construction of Chinese geological borehole database, we need to carefully summarize the results and experiences of the previous pilot construction of Chinese geological borehole database, learn from the contents and experiences of foreign geological borehole database construction, change the thinking of geological borehole database construction, and thoroughly and systematically study the collection contents and requirements of geological borehole data, classification rules, data standardization, data model, and data organization. We will study in detail and systematically the collection content and requirements, classification rules, data standardization, data model, data organization and management system, data quality control system, system design and integration, unified management technology and method, and efficient service utilization technology and solve the key theories, methods, and technologies to promote the construction of Chinese geological borehole database.

### 3. Methods

*3.1. Model Structure.* When remote sensing technology is used in mineral search, it is necessary to strengthen the ability of remote sensing technology information processing on the one hand and actively promote the effective combination of remote sensing images and geological maps on the other. Once the geological survey is conducted, it is important to process all the information in order to obtain accurate remote sensing images. This would help in laying a solid foundation for the smooth implementation of future search work for acquiring minerals. The flow of the algorithm is shown in Figure 2.

Step 1: first, the binary image is preprocessed, and the noise is filtered by morphological filtering method to reduce the influence of noise. Step 2: the long and short axis direction angles and geometric methods obtained by using the invariant distance technique are used to adjust the target spindle to the vertical direction. Step 3: various operators can be used to detect the target edge, because the calculation of line moment needs to mark the target boundary a sequence, so the boundary tracking extraction algorithm is used in this algorithm to edge the target image directly. Step 4: calculate the target line moment feature and extract the normalized projection of the target on the horizontal  $x$  and vertical  $y$  axes, the projection profile can well reflect the target shape structure. Step 5: match the line moment features with the precomputed template feature library and roughly select  $M$  most likely target types from  $N$  samples of the template library according to the minimum Euclidean distance and maximum correlation coefficient combined with the

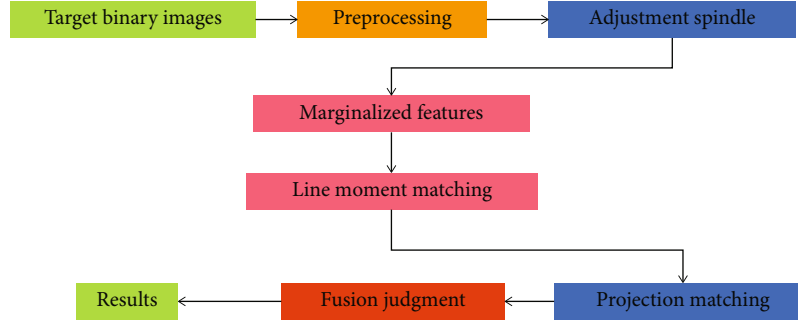


FIGURE 2: Algorithm flow.

rule judgment. Since  $M \ll N$ , the efficiency of subsequent exact matching recognition is ensured ( $M = 5$ ,  $N = 50$  in this experiment). Step 6: match the target  $x$ - and  $y$ -axis projections with the screened  $M$  possible template samples, calculate the similarity and correlation coefficients of the two axes contours, respectively, based on certain thresholds, and use fuzzy inference techniques to fuse the recognition results. After two levels of classification judgments, coarse search based on linear moments and exact matching based on graphic contours, the recognition effect is improved and the computing time is reduced.

**3.2. Invariant Linear Moments.** Invariant moments are divided into two types: surface moments and line moments, and surface moments are used for invariant moments of region shape recognition, which are more time-consuming. The fast algorithm for calculating the invariant moment of the region based on the boundary, the face moment is several times more time consuming than the line moment, and the recognition rate is 96.18% for the face moment and 94.16% for the line moment, which shows that the operation efficiency of the line moment is much higher when the difference in accuracy is not large. Some definitions about line moments: for the target contour code chain  $L$  in digital images:  $L : (x_i, y_i)$  order line moments are

$$m_{pq,L} = \sum_{i=1}^N x_i^p y_i^q \Delta l_i, \quad (1)$$

where  $\Delta l_i$ ,  $N$  is the number of pixels on the boundary curve. The shape center of the target region.

$$\bar{x} = \frac{m_{10}}{m_{00}}, \bar{y} = \frac{m_{01}}{m_{00}}. \quad (2)$$

The central moment is defined as

$$\mu_{pq,L} = \sum_{i=1}^N (x_i - \bar{X})^p (y_i - \bar{Y})^q \Delta l_i. \quad (3)$$

The normalized central moment is given by

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{1+p+q/2}}. \quad (4)$$

The proportional, rotationally invariant momenta can be calculated based on the normalized central moment of the line moment.

**3.3. Target Image Adjustment.** In preprocessing, the target image principal axis (symmetry axis of coal mine and ship) is adjusted to vertical direction, first, it can minimize the error of line moment calculation caused by image rotation, and second, it is convenient to extract the projection on  $x$  and  $y$  axis. This step is very critical and directly determines the subsequent recognition effect. The invariant second-order moment represents the rotational moment of inertia of the image with the formula

$$\theta = \frac{1}{2} \arctan \left( \frac{2u_{11}}{u_{20} - u_{02}} \right). \quad (5)$$

$\theta$  represents the angle between the long axis of the target image and the horizontal or vertical axis. By rotating the image by the angle  $-\theta$ , the target can be adjusted to the horizontal or vertical position of the airplane (ship) body. This method is suitable for target types with relatively disparate length and width, and the adjustment result error is very small, generally less than 0.02 degrees. Some large aircraft whose main long axis direction is not the fuselage or the direction of the wing line perpendicular to the fuselage, the main axis orientation angle direction method will fail.

**3.4. Feature Extraction and Objective Classification.** Calculate the linear invariant moment. Extract the projection on  $x$  and  $y$  axes as a one-dimensional sequence, which well reflects the profile characteristics of the target and can reduce the matching time.

The target line moments are matched with line moments, and the matching is based on the minimum distance principle and similarity combination method. Using normalized Euclidean distances.

$$D(i) = \frac{\sum_{j=1}^m [I(j) - I_T(i, j)]^2}{[I(j) - I_T(i, j)]^2}. \quad (6)$$

(1) Target line moment matching line moment equation in which  $D(i)$  is the distance between the target line moment and the  $i$ th template,  $I(j)$  is the  $j$ -th component of the target line moment feature,  $I_T(i, j)$  is the  $j$ -th component of the  $i$

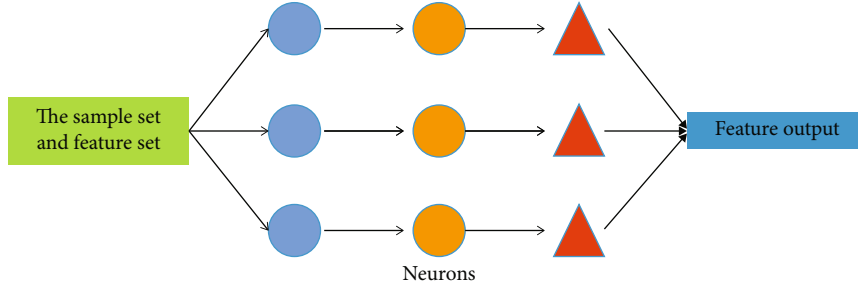


FIGURE 3: Feature processing flow.

-th template (template) feature, and  $m$  is the number of invariant moments  $I$  feature components. In the experiment, it is found that when  $m = 4$ , i.e., only  $I_1 - I_4$  are taken to achieve a good classification effect. Because the template feature vector is dense, here, all the template feature data are averaged and used as the center to do similar correlation coefficient improvement with the formula: matching based on the principle of minimum distance and similarity combination method. Using the normalized Euclidean distance

$$r(i) = \frac{\sum_{j=1}^m \{ [I(j) - \bar{I}_T(j)] [I_T(i, j) - \bar{I}_T(j)] \}}{\left\{ \sum_{j=1}^m [I(j) - \bar{I}_T(j)]^2 \times \sum_{j=1}^m [I_T(i, j) - \bar{I}_T(j)]^2 \right\}^{1/2}}, \quad (7)$$

where  $r(i)$  is the similarity coefficient between the target and the  $i$ -th template, and  $I(j)$  is the centered value of the template feature to be selected. The improved similarity is distributed between  $[-1, 1]$ , and the interval can be transformed to  $[0, 1]$ .

$$r_y(i) = \sum_{j=1}^r \left\{ [P_y(j) - P_{TY}(j)] [P_{T_y}(i, j) - \bar{P}_{T_y}(j)] \right\},$$

$$\sum_{j=1}^Y \left\{ [P_y(j) - \bar{P}_{TY}(j)]^2 \times \sum_{j=1}^Y [P_{T_y}(i, j) - \bar{P}_{T_y}(j)]^2 \right\}^{1/2}. \quad (8)$$

Feature selection, i.e., the creation of feature subsets so that the constructed feature space can achieve better results in the end. A good feature selection can improve the performance of the model and reveal the characteristics of the data and the underlying structure more easily, which is important for further improvement of the model and the algorithm. Feature importance is a technique to select features using a trained supervised classifier, which is widely used due to its simplicity and practicality. The common methods of feature importance include RF, GBDT, Light GBM, and XG Boost. Random forest is an ensemble model that is used to solve classification and regression problems. It involves construction of multiple decision trees during training of the data. The output of the random forest is the class selected by majority of the trees. The gradient boost decision trees (GBDT) algorithm uses an ensemble of decision trees for

the prediction of the target label. The light gradient boosting machine (LightGBM) is based on the decision tree technology that increases the efficiency and memory usage of a model and is used for ranking and classification of other machine learning tasks. In this paper, the XG Boost algorithm is used for feature selection after comprehensive evaluation through experiments. XGBoost is often referred as an “All in one” algorithm as it can be used for ranking, classification, regression, and various user specific prediction problems. XGBoost has been a predominant choice in various machine learning implementations. As an example, the study in [23] used XGBoost for the development of subsurface geological cross-section from boreholes of specific sites on the basis of prior geological knowledge. The study in [24–26] used XGBoost modeling for performing three dimensional mineral mapping on the basis of metallogenic systems and geological anomaly theories. The feature processing flow is shown in Figure 3.

**3.5. Drilling Database.** The drill hole database contains data objects including project information, work area information, and drill hole data, and the drill hole data involves coal-field, petroleum, and uranium data. In the model design stage, based on the important geological borehole database of China and relevant standards and specifications of nuclear industry, UML modeling language based on object-oriented technology is used to gradually refine different data objects, determine the attributes of data objects and their relationships with each other, map the database relationship schema, determine the attributes and codes of the relationship schema, and adjust the tables for redundancy control to make them achieve a reasonable relational paradigm. The database structure diagram is shown in Figure 4. The database construction architecture adopts a distributed construction and centralized aggregation approach (see Tables 1 and 2), using Access database for the distributed construction database, Oracle database for the aggregated central database, and Geo data base format for spatial data storage.

The Access database is a traditional relational database, which is a lightweight file-level database, easy to use, and suitable for distributed construction database, while the central database manages a large amount of data and undertakes data processing and analysis. Data base format is also stored in the Oracle database. In the conceptual design stage, we first analyze the similarities and differences in the content and format of different types of borehole data entities,

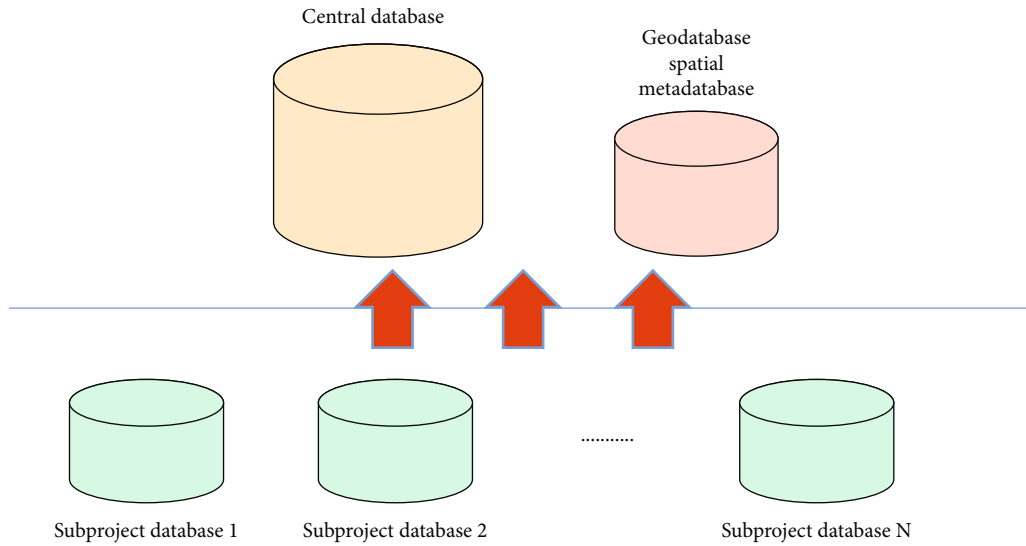


FIGURE 4: Database structure diagram.

TABLE 1: Main data entities and types of library construction.

Data entities	Type	Mineral species involved	Collection sources
Geological cataloging lithology	Observation	Uranium, coal, oil	Resulting information, field survey
Stratigraphic stratification	Observation	Uranium, coal, oil	Results, field survey
Rock color	Observation	Uranium, coal, oil	Results, field survey
Logging curves	Observation	Uranium, coal, oil	Result information, field survey
Hydrological observations	Observation	Uranium	Results, field survey
Sample sampling	Observation	Uranium	Result information, field survey
Core logging	Observation	Uranium	Result information, field survey
Curvature measurement	Observation	Uranium, coal, oil	Result information, field survey
Rock core photos	Observation	Uranium	Field survey
Logging interpretation lithology	Explanation	Uranium, coal, oil	Results
Logging interpretation results	Explanation	Uranium	Results
Basic chemical analysis results	Explanation	Uranium	Results
Comprehensive column lithology stratification	Explanation	Uranium, coal, oil	Results
Raw geological logging	Observation	Uranium	Field survey

TABLE 2: Master code for partial relationships in the drill hole database.

Relationships	Main code
Projects	Project number
Working area	Work area number
Mineral rights	Work area number, mineral right number
Boreholes	Work area number, drill hole number
Lithology	Work area number, drill hole number, lithology number
Stratigraphy	Working area number, drill hole number, stratigraphic number
Rock color	Workings number, drill hole number, color sequence number
Logging curves	Working area number, drill hole number, logging number
Logging configuration	Zone number, drill hole number
Sampling information	Workover number, drill hole number, sampling number

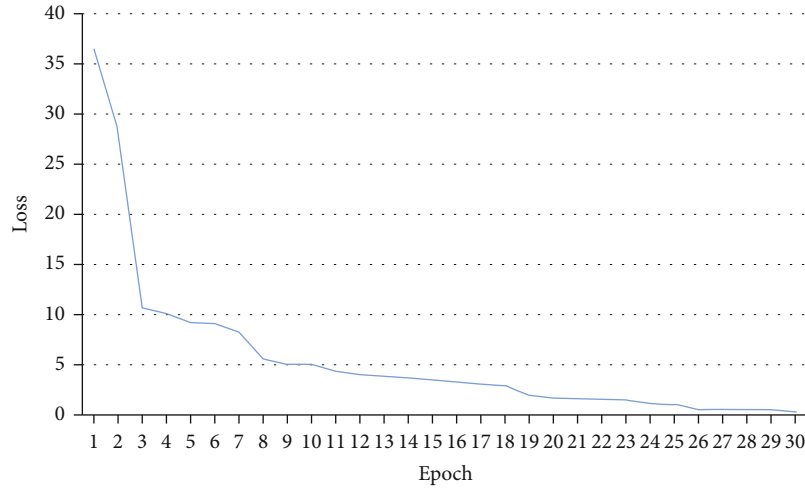


FIGURE 5: Loss degradation curve during training.

abstract the data from the database application requirements, identify the borehole observation and interpretation entities, and determine the corresponding relationships.

## 4. Experiments and Results

*4.1. Experimental Data.* The remote sensing image data used in this paper is a nonpublic dataset of a domestic mineral exploration company in China, which is a large size and high-resolution remote sensing image obtained by IKONOS sensor, covering a mining area in northwest province of China. The image is fused by GS algorithm with a resolution of 1 m and contains 4 bands, namely, blue, green, red, and near infrared bands. For the image data, some areas are selected as the study area and the verification area, and the precise interception is performed by e-Cognition software.

*4.2. Construction of Multifeature Space.* In this paper, we use the built-in multiscale segmentation algorithm in e-Cognition software to perform object-oriented segmentation of remote sensing images and obtain object features. The segmentation scale parameter is an abstract threshold that determines the maximum heterogeneity allowed in the image segmentation result. In this paper, we use estimation of scale parameter (ESP) scale evaluation tool to obtain the optimal segmentation scale parameter, which represents the segmentation effect by calculating the local variance (LV) of the homogeneity of the image object under different segmentation scale parameters as the average standard deviation of the segmented object layer. When the LV variation rate is the largest, i.e., the peak value, the segmentation scale value corresponding to this point is the best segmentation scale. First, the ESP scale evaluation tool was used to obtain several suitable segmentation parameters, and then, the optimal segmentation scale was selected by visual discrimination of the segmentation effect. The loss degradation curve and performance improvement during training are shown in Figures 5 and 6, respectively.

*4.3. Comparative Analysis of the Experimental Results of the Study Area.* In order to evaluate the accuracy of the recognition results of the study area, the accuracy of the classification results was verified by using random and uniformly distributed sample points, and the overall accuracy and Kappa coefficient of the recognition results were calculated by establishing the confusion matrix, as shown in Table 3.

The Kappa coefficient is calculated based on the confusion matrix, which is usually used as the main indicator to check the consistency and can also be used to reveal the classification effect. The results generally fall between 0 and 1, and the higher the value, the higher the consistency. The kappa coefficient obtained by the experimental method in this paper is 0.83, which further indicates that the urban remote sensing image target recognition based on multifeature space and its optimization has high recognition ability. After analyzing the recognition results of the study area, we found that several vegetation samples were misclassified into shadows. The differentiation ability of vegetation and shadows in this research method needs to be improved. Further analysis of the reasons for this phenomenon includes three aspects: (1) the complexity of the vegetation in the study area is high, which has a great negative impact on the accurate recognition; (2) some features of some vegetation areas are too similar to shadows; (3) the vegetation and shadows are not accurately segmented when extracting the object features, and this leads to the subsequent inability of accurate recognition. Comparing the recognition results of the two traditional methods with this method, we can find that the overall accuracy and kappa coefficient of this method have been greatly improved, which directly indicates that the urban remote sensing image target recognition based on multifeature space and its optimization is a feasible and effective method.

*4.4. Experimental Analysis of Borehole Database.* The national geological borehole database construction unit (provincial geological borehole database construction unit) should conduct quality evaluation on the basis of data



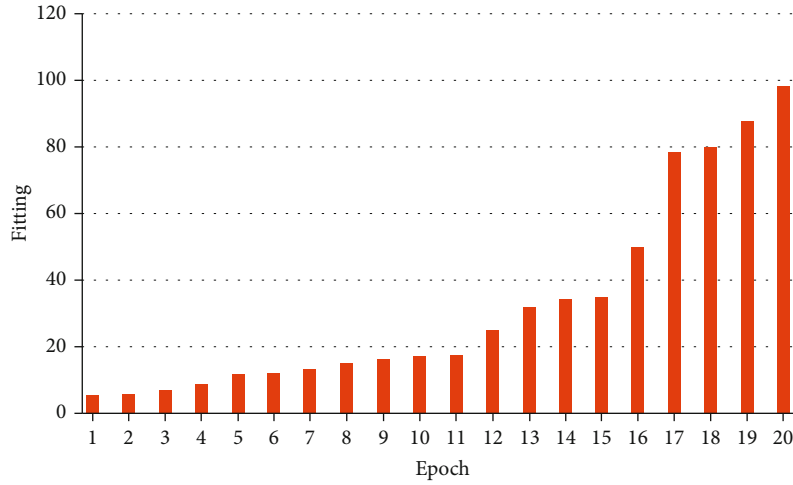


FIGURE 6: Performance improvement curve during training.

TABLE 3: Experimental parameter setting.

Methods	Accuracy (%)	Kappa coefficient
Image based	77.28	0.72
Object-based	82.45	0.79
Based on multiple feature spaces and their optimization	87.89	0.83

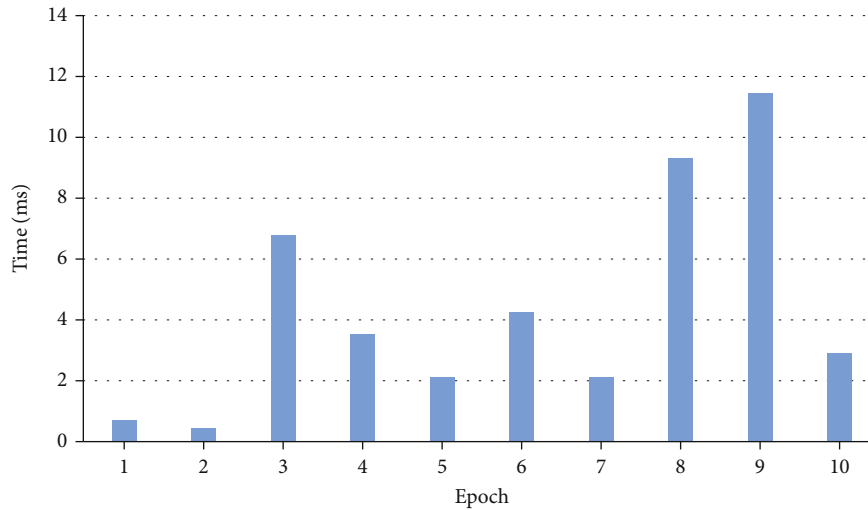


FIGURE 7: Database request time delay stability test.

quality inspection and acceptance of the geological borehole data results submitted by the provincial geological borehole database construction unit (data production unit). The content of the commentary is mainly a comprehensive evaluation of whether the geological borehole database results complete the work requirements, whether the data quality meets the acceptance requirements, and whether the submitted work reports and data quality control documents are complete. For geological borehole data quality evaluation, comments should be made against the geological borehole data quality evaluation. In data quality inspection and acceptance, each occurrence of sunlight defect *A* is counted as 1,

light defect *B* is counted as 2, heavy defect *C* is counted as 9, fatal defect *D* is counted as 16, and the total number of checked attribute items is *N*. The total score is *S*. The formula for calculating the score *S* is as follows.

$$S = \left( 1 - \frac{1 * A + 2 * B + 9 * C + 16 * D}{N} \right) * 100. \quad (9)$$

Database request time delay stability test is shown in Figure 7, it can be found that it randomly sends 10 requests, and the database can be stable response. Data quality

TABLE 4: Drilling database quality inspection main content and inspection means.

First-level inspection content	Secondary inspection content	Level
Data integrity	Number of boreholes, charts	Excellent
	Required items	Good
	Repeated, missing important attribute items	Excellent
	Duplicate, missing attribute data table	Good
	Duplicate, missing data records	Excellent
Data accuracy	Content of important attribute items	Good
	Drill hole coordinate positioning	Excellent
	Diagramming and viewing check of drill hole attribute data	Good
	Correctness of chart linking	Excellent
	Diagram scanning quality	Good
Logical consistency	Consistency of database structure	Excellent
	Consistency of data table structure	Excellent
	Consistency of data item value fields	Excellent
	Data format consistency	Qualified
	Data record association consistency	Good
	Chart format, file name format check	Excellent
	Data table and chart correlation	Qualified

evaluation, according to the grade characterizing the quality of geological borehole data, is divided into four grades: excellent, good, qualified, and unqualified, based on the percentage system, with the following criteria: (1) excellent:  $S > 90$  points; (2) good:  $90 > S > 75$  points; (3) qualified:  $75 > S > 60$  points; and (4) unqualified:  $S < 60$  points. When the quality evaluation score of geological borehole data is greater than or equal to 90, the quality comment is excellent; when it is less than 90 and greater than or equal to 75, the quality comment is good; when it is less than 75 and greater than or equal to 60, the quality comment is qualified; when it is less than 60, the quality comment is unqualified. When the review is unqualified, the geological borehole database should be returned to the corresponding unit for modification, improvement, redoing, or reworking, and then review and reinspection should be conducted after modification and improvement. The review and reinspection can be carried out several times until the quality of the submitted geological borehole data meets the quality control requirements of geological borehole database construction. Table 4 shows the results of the proposed database testing, and all indicators are above qualified and can be used for actual mineral development.

## 5. Conclusion

In summary, today, the mining of mineral resources directly affects the national economic development, to be able to do a good job in geological and mineral mining requires adequate geological exploration and reasonable application of mineral search technology to ensure that the mineral exploration work can meet the needs of modern development. Remote sensing technology plays a very important role in many fields, and the application of this technology in geological

exploration has greatly promoted the development of geological exploration work in China. The scientific use of modern information imaging technology can provide good conditions and greater convenience for geological exploration and geological prospecting work. Remote sensing technology in geological prospecting can significantly improve the comprehensive level of geological exploration, strengthen the accuracy of geological prospecting based on advanced technology, and thus promote the smooth development of geological exploration and prospecting work in China. We create a drilling database management system to manage geological drilling data scientifically and release geological drilling information and drilling dynamics in real time to provide users with a convenient and fast data sharing channel and provide early warning service of geological disasters for coalfield exploration and development. In the specific survey, it is necessary to clarify the geological landscape, collect relevant information comprehensively, improve the accuracy of geological survey, and ensure that it is carried out to a high standard. Mineral exploration enterprises should also actively introduce advanced technology and equipment to fundamentally improve the efficiency of geological and mineral exploration and mineral search.

## Data Availability

The datasets used during the current study are available from the corresponding author on reasonable request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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