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Research Article

Design and Realization of the Intelligent Design System for Tunnel Blasting in Mine Based on Database

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With the improvement of informatization and standardization of mine development, it is an inevitable trend to apply computer technology to the intelligent design of tunnel blasting excavation. Seeking to the problems existing in the intelligent design system of blasting excavation, a new intelligent design system of blasting excavation is constructed from the perspective of database technology. The new intelligent design system adopts the design of central database system and subuser rights to meet the data synchronization and sharing among different users. At the same time, the new system also extracts blasting design parameters and actual engineering data and designs a more reasonable and comprehensive database structure, database logic, and data word table. Based on the T-S fuzzy neural network model, the intelligent search rules of excavation blasting data are also constructed in the new system. Finally, based on Oracle and VB.NET as the new system development platform, MFC, and ADO as the new system development technology, the new intelligent design system for tunnel blasting and excavation was completed. The implementation of the new system addresses the needs of blasting data information storage and search and lays a foundation for the informatization and standardization of tunnel excavation blasting.

1. Introduction

1.1. Research Status of the Intelligent Blasting Design System.
Tunnel excavation is the most basic part of mining. The drilling and blasting method have the advantages of flexibility, convenience, and speed, which make the drilling and blasting method widely used in tunnel design and construction [1–3]. At present, the parameter design and data management are usually compiled manually, which leads to a series of problems in actual engineering, such as nonstandard blasting design, complex, and fragmentary blasting parameters. Therefore, how to change the backward situation of manual design calculation, drawing, and manual compilation and management of blasting data has become an urgent problem in the field of blasting and tunnel engineering [4–6]. With the continuous development of information technology and computer hardware, the concept of digital mines continues to deepen and improve. It has become an inevitable trend to use computer technology to collect and summarize blasting parameters and to intelligently design and manage blasting and construction information [7, 8]. In recent years, many experts and scholars have developed a series of blasting parameter management systems and blasting and tunneling design software. For example, Li developed a deep hole blasting design system for water conservancy and hydropower projects based on the Access and Visual Basic platform [9], Yang et al. based on rules and typical case reasoning mechanisms, while using production rules and maximum matching reasoning strategies to achieve coal mine tunnel blasting intelligent design software [10], Zhang et al. combined software engineering and artificial intelligence to develop an intelligent system for tunnel blasting design [11], Mamurekli developed a set of open-pit mining intelligent design software based on the expert knowledge base and black box theory [12], and Chung and Preece developed a database system based on the SQL language platform [13]. However, the
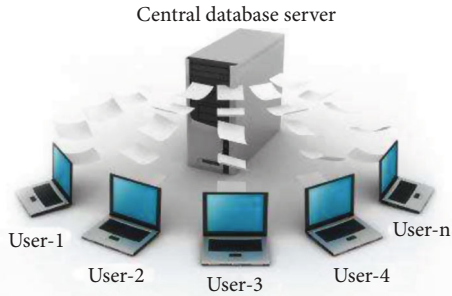
FIGURE 1: Central database system model.

current mainstream intelligent design and data management systems for tunnel blasting still have problems such as insufficient development depth, incomplete data synchronization, and chaotic logic flow [14]. In tunneling and blasting, whether it is parameter management or intelligent design software development, the key issue is the completeness and accuracy of the data [15, 16]. Therefore, to fundamentally solve the existing problems in the current tunnel blasting design system is only by solving the data problem. This paper takes database technology as the key and combines it with neural network technology and computer programming technology to develop a new intelligent tunnel blasting design system, which realizes the use of computer methods instead of manual management of tunnel blasting data and further promotes informationization and standardization of tunnel blasting.

1.2. Problems in Existing Blasting Intelligent Design System

1.2.1. Data Cannot Be Synchronized and Shared. Due to the development purpose and development platform, most of the current mining and blasting database systems are only attached to the software alone and cannot complete the real-time sharing and interaction of data between users. This leads to two problems when users use the database system: one is that data must be updated manually or imported manually, which greatly reduces the efficiency of work and the accuracy of data; the other is that users are using existing data for data. In management and intelligent design, there are obvious differences in the results of queries or calculations.

1.2.2. Selection of Blasting Data Is No Comprehensive and Data Flow Is Chaotic. The key to the blasting intelligent design system is data. The incomplete data content and the confusion of the data logic will prevent users from entering and querying the corresponding blasting data accurately and efficiently. At the same time, this problem also makes the subsequent development of the database suffer from design and function incompleteness.

1.2.3. Insufficient Use of the Database. At present, in the mainstream blasting design system, the development of the database is usually only used as a module of the system or as a data management tool and only realizes the functions of data storage calling and management. The functions are relatively simple, especially the search function, which is usu-

ally based on the database development software. Corresponding to the search mode, there is no intelligent search matching the characteristics of the tunneling blasting parameters.

2. Key Issues of Building an Intelligent Design System for Mine Tunnel Blasting Based on Database Technology

The design of tunnel blasting is based on engineering empirical data. In this design process, there are many inherent connections between parameters that have not been understood. Therefore, finding the relationship between blasting design parameters and blasting results based on tunneling blasting data and through some mathematical methods has become an important method to analyze and solve problems in tunneling blasting. Data is the basis for analyzing blasting problems, so the development of intelligent design system is based on database.

Given the existing problems in the development and implementation of the current blasting and tunneling database system, the paper studied the core issues of the construction of the mine tunneling blasting database system from the perspective of database technology, which is mainly reflected in the following three aspects:

2.1. Database System Structure and User Permissions

2.1.1. Database Architecture. The construction of the database system is related to the basic operating form and structure of the database system and determines how all users process blasting data. To solve the problem of data sharing and synchronization among users, the new intelligent design system adopts a central database structure system, and the system model is shown in Figure 1. The new system adopts a unified central database server when designing the database. The operation interface is only used as a front platform to reflect users' data operations. Data between users only interact through the central data server to complete data synchronization and sharing.

Figure 2 shows the basic workflow of a central database system model. The overall framework of the system is divided into four levels: instance, database, database server, and interface. The running process of the central database system: after data, commands are issued by multiple users to the operation interface layer, the unified database system server layer responds, then the syntax analysis, compilation, and execution are performed in the memory area of the instance layer, then the modified data is written into the data file, the modification information of the database layer is written into the log file, and finally, the execution result of the data command is returned to the operation interface layer to complete the user's management of blasting data and the application of the database system.

2.1.2. User Permission. In the database operation of the new system, three different types of user attributes are designed, and the corresponding permissions for different user attributes are set accordingly. Its purpose is to facilitate the
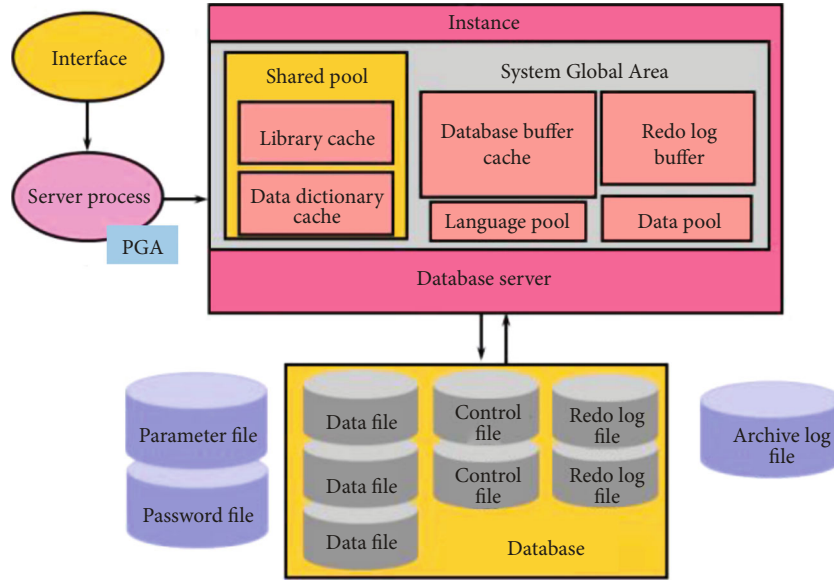
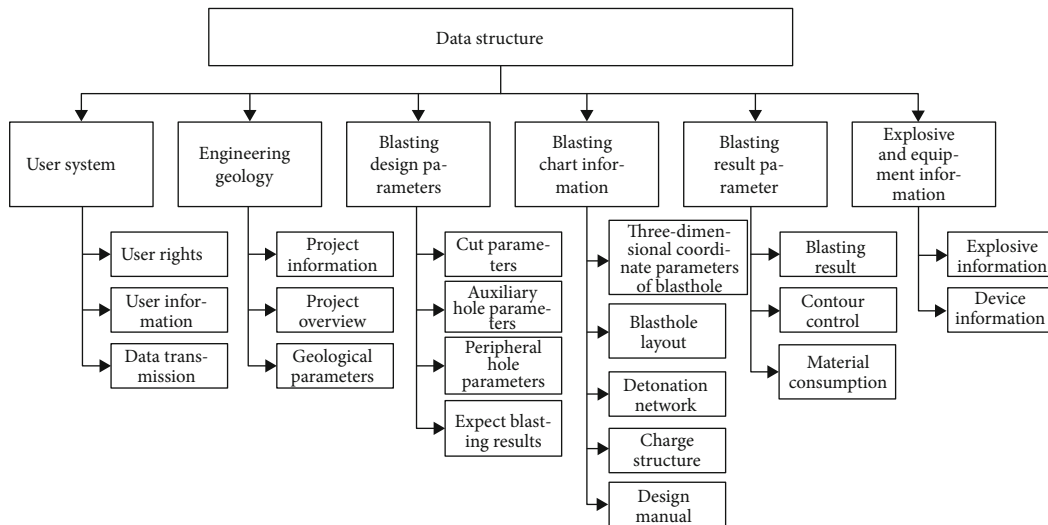FIGURE 2: Basic architecture of the database system operation.

FIGURE 3: Date structure of intelligent design system for mine tunnel blasting based on database.

TABLE 1: User permission design.

User attributes	Operation authority and content		
	Self-data	Not self-data	Database system
Common user	Modify	Access	Non
Advanced user	Modify	Modify	Non
System administrator	Modify	Modify	Modify

management of the excavation blasting data by different users, ensure the security of data between different users, and further realize the sharing and synchronization of data. The specific design scheme is shown in Table 1.

2.2. Database System Design. Database system design is the core part of the new intelligent design system for tunnel blasting, which ensures the reasonable and efficient operation of the new system. The database implementation process includes three parts: date content and structure (requirement analysis), data flow and logic (logical design), and data table design (physical design).

2.2.1. Date Content and Date Structure. The data content refers to all the data involved in the process of tunnel blasting which should be included in the database, and the data structure refers to the structure system of these data stored in the database.

(1) Data Content. According to references [17–20], in blasting design content and actual blasting experience, the data of tunnel blasting excavation should include three parts: engineering-geological parameters, blasting design
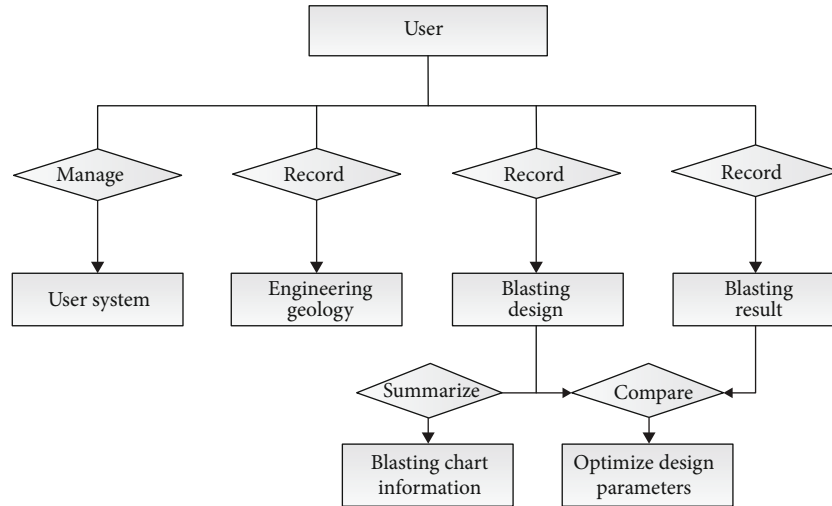
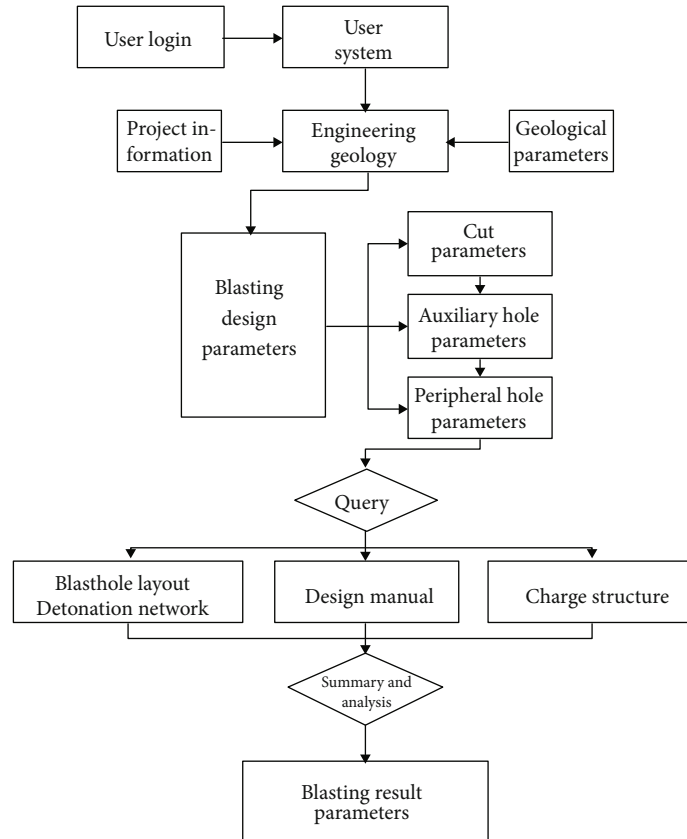Figure 4: Global E-R diagram of the intelligent design system for mine tunnel blasting based on database.

Figure 5: Data logic of intelligent design system for mine tunnel blasting based on database.

parameters, and blasting result parameters. Among them, the suitable engineering-geological parameters include the size of the design roadway section, surrounding rock type, rock f value, rock integrity, and groundwater. The suitable blasting design parameters include cutting mode and parameters, peripheral hole parameters, single-shot charge quantity, design cycle footage, and blasting hole layout parameters.

The suitable blasting result parameters include the actual cycle footage, explosive unit consumption, explosive consumption, and over-under excavation values. Overall, a total of 96 data contents were designed into the new system.

(2) Date Structure. To facilitate user operation and make the tunnel blasting data better management and query, three

TABLE 2: Design parameters of the peripheral hole.

| Field name	Field data type	Length	Additional attributes	Remarks
Blasting section number	Text	30	Required	Index
Number of upper holes	Numeral	8	Required	Non
Depth of upper holes	Numeral	8	Required	Non
The angle of upper holes	Numeral	8	Required	Non
Distance between upper holes and contour	Numeral	8	Required	Non
Number of side holes	Numeral	8	Required	Non
Depth of side holes	Numeral	8	Required	Non
The angle of side holes	Numeral	8	Required	Non
Distance between side holes and contour	Numeral	8	Required	Non
Number of bottom holes	Numeral	8	Required	Non
Depth of bottom holes	Numeral	8	Required	Non
The angle of bottom holes	Numeral	8	Required	Non
Distance between bottom hole and contour	Numeral	8	Required	Non
Hole diameter	Numeral	8	Required	Non
Charge method	Text	30	Required	Non
Charge	Numeral	8	Required	Non
Forward view of the blasthole layout	Annex	-	Storage path	File
Side view of the blasthole layout	Annex	-	Storage path	File
Design time	Time	42	Required	Non
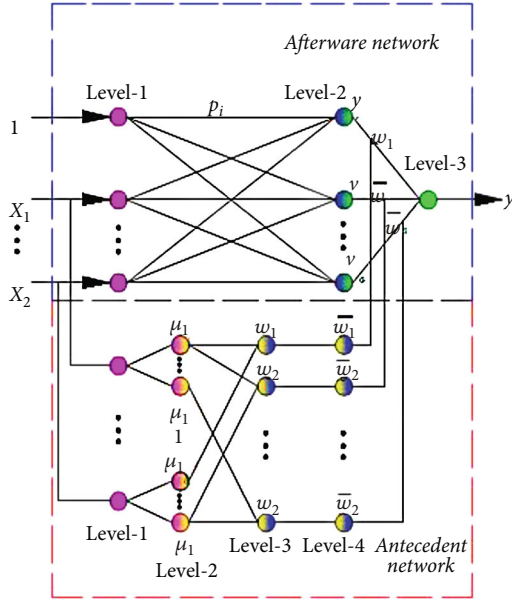
FIGURE 6: Fuzzy neural network structure based on T-S model.

parts of data content are extended to six types of data. The structure is illustrated in Figure 3. These six types of data are data structures, including user system module, engineering geology module, blasting design parameter module, blasting chart information module, blasting result parameter module, explosives, and equipment information module. The user system module manages user rights, user information, user data sharing, and synchronization. The engineering geol-ogy module manages the specific information about the project and the geological conditions of the blasting area. The blasting design parameter module and the blasting chart information module are the core content of data, which manage blasting design parameters and design drawings. The blasting result parameter module manages the actual postblast data of each blasting scheme. The explosive and equipment information module manage the explosive and equipment information during blasting.

2.2.2. Data Logic and Flow. To simplify the database design and improve the utilization rate of the database word table, the database adopts the relational model in the logic design. When designing a relational database, it is necessary to establish a logical model for it. The logical model can be represented by a graph (E-R diagram) composed of entities and relationships. Due to space limitations, only the global E-R diagram of the system is shown, as shown in Figure 4. At the same time, according to the data correlation in the tunnel blasting design, the data flow diagram in the database is given, as shown in Figure 5.

2.2.3. Data Table Design. The design content of each corresponding data table is determined by the data content and data flow direction of tunnel blasting, including system user table, engineering item table, geological data table, cutting parameter table, and peripheral hole design table. The total number of data tables is 38 sheets. The design of each data sheet includes the following factors: field name, field data type, length, additional attributes, and remarks. Due to space limitations, only the datasheet of peripheral hole parameters
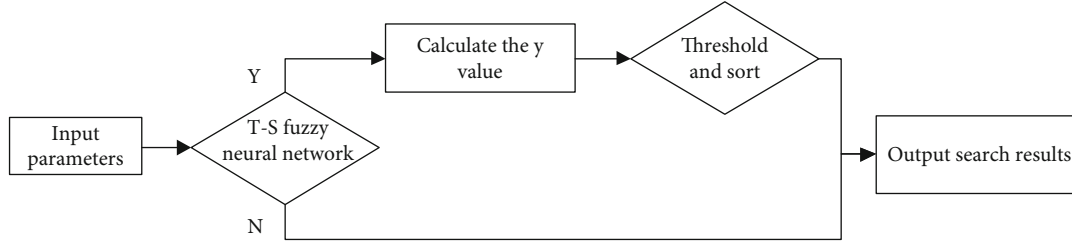
FIGURE 7: Data search flow chart of the database.

TABLE 3: Fuzzy digital index of joint fissure.

Criteria for the classification	<1/m	1-3/m	3-5/m	5-7/m	>7/m
Fuzzy index	0.1	0.3	0.5	0.7	0.9

is taken as an example. The specific content is shown in Table 2.

2.3. Data Intelligent Search. There are two main search behaviors in the new system. One is to search for existing user names or project names to obtain corresponding blasting data. The other is to search for design conditions or expected design results to obtain corresponding or similar blasting design data. The former adopts a common search model and can be realized by using the search function of the database itself. The latter is an intelligent search model, which can be realized only by designing a matching intelligent search algorithm. Considering that there is a certain "fuzziness" in blasting parameters during the intelligent search, and the membership weights between search parameters need to be calculated, the intelligent search model is researched and designed based on the T-S fuzzy neural network model to realize the intelligent search behavior of the new system.

Steps of intelligent search: first, collect the existing blasting design parameters through field tests and reference records. The parameters include geological condition parameters, blasting design parameters, and blasting result parameters. Secondly, the collected data is entered into the database, and part of the data is fuzzy and normalized to unify the data calculation standard. Subsequently, using T-S artificial neural network technology to analyze the influence of geological conditions and blasting design parameters on the blasting results determines the relationship between geological conditions, blasting design parameters, and blasting results, that is, determines the weight relationship between each parameter. Finally, by judging the weight relationship of the input search, the result of the intelligent search is determined.

2.3.1. T-S Fuzzy Neural Network Calculation Rules. The "T-S fuzzy model" has the characteristics of automatically updating and continuously correcting the membership function

of fuzzy subsets [21]. The neural network structure of this model is shown in Figure 6.

The T-S fuzzy model is usually defined in the form of the following "if-then" rule. When the rule is R^i, its fuzzy inference logic is as follows:

R^i: if x_1 is A_1^i, x_2 is A_2^i, ..., x_k is A_k^i, then $y_i = p_0^i + p_1^i x_1 + \cdots + p_k^i x_k$.

A_1^i is the sample set of all parameters of the fuzzy system, $p_j^i (j = 1, 2, 3, \cdots, k)$ is the parameter of the fuzzy system, and y_i is the calculation output of the fuzzy rule. The above inference rules indicate that the determined output y_i is a linear combination of samples corresponding to the fuzzy input x_i.

Suppose that for the $x = [x_1, x_2, x_3, \cdots, x_k]$ corresponding to the input parameter, the membership degree of each input variable x_i is first calculated by fuzzy rules:

$$\mu_{A_j^i} = \exp\left(\frac{-\left(x_j - c_j^i\right)^2}{b_j^i}\right) j = 1, 2, \cdots, k; i = 1, 2, \cdots, n. \quad (1)$$

c_j^i and b_j^i represent the center and width of the input function; c_j^i is determined by input parameters, and b_j^i is determined by all input parameters. c_j^i and b_j^i need to normalize all samples and parameters before calculation; k is the input dimension, and n is the number of fuzzy subsets. Then, the fuzzy calculation of each membership degree is performed by the method of continuous multiplication by the fuzzy operator:

$$\omega^i = \mu_{A_j^1}(x_1) \times \mu_{A_j^2}(x_2) \times \cdots \times \mu_{A_j^k}(x_k) \ i = 1, 2, \cdots, n. \quad (2)$$

Obtain the model output value y based on the fuzzy calculation result:

$$y = \sum_{i=1}^{n} \omega^i \left(p_0^i + p_1^i x_1 + \cdots p_k^i x_k\right) / \sum_{i=1}^{n} \omega^i$$

$$= \sum_{i=1}^{n} \bar{\omega}^i \left(p_0^i + p_1^i x_1 + \cdots p_k^i x_k\right). \quad (3)$$

After the T-S fuzzy neural network completes the calculation, it sorts in descending order according to the magnitude of the value, sets a threshold Y, and makes the following reasoning:

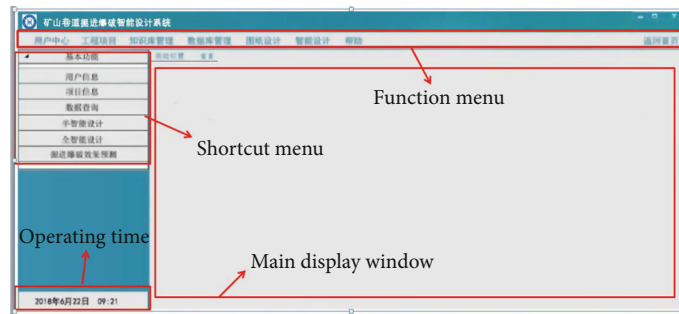FIGURE 8: The startup interface of the intelligent design system for mine tunnel blasting based on database.

FIGURE 9: The operation interface of the intelligent design system for mine tunnel blasting based on database.

If: $y > = Y$, then output "Data sample number corresponding to y value."

2.3.2. The Process of Data Intelligent Search. The process of intelligent search is shown in Figure 7, which contains two processes:

(1) Determine the Search Parameters of the Input Fuzzy Neural Network. Considering the user's usage habits and blasting site, the intelligent search selects two types of parameter input modes, one is based on geological conditions, and the other is based on blasting parameters. Geological condition search data = {hydrological conditions, joints and cracks, roadway section area, roadway height, width, surrounding rock strength f value, rock mass stability}. Blasting parameter search data = {cutting method, the total number of blastholes, charging method, explosive unit consumption, maximum single-shot charge, cycle footage}. Among them, some fuzzy indexes (joint cracks) and text indexes (hydrological conditions) need to be fuzzified mathematically. Due to space limitations, only the treatment values of {joint cracks} are shown in Table 3.

(2) Fitting of Blasting Parameters Based on T-S Model Fuzzy Neural Network. Based on the blasting data and input conditions, the T-S fuzzy neural network will perform corresponding self-learning and calculate the corresponding weights. The purpose of self-learning is to analyze the relationship between existing blasting data, and the purpose of weight calculation is to obtain the specific weight of decision data under input conditions. At this time, the input parameter in the new system is the fitting coefficient of the neural network = {error calculation, coefficient correction, parameter correction} (generally it has been designed in advance). Finally, the system will output the search results according to the data output rules and complete the intelligent search at the same time.

3. Realization of Intelligent Design System for Mine Tunnel Blasting and Driving Based on Database

3.1. System Development. The new system chose Oracle as the database development platform [22], VB.NET as the system software development platform [23], MFC, and ADO as the development technology [24] and finally realized the mine tunnel intelligent blasting design system. Figure 8 shows the startup interface of the new system. Figure 9 shows the operation interface of the new system.

3.2. Data Collection. Data collection adopts two methods: engineering site and document extraction, of which the engineering site is the main one. Figure 10 shows a site parameter collection; Figure 10(a) is the collection of blasting design parameters, and Figure 10(b) is the collection of blasting result parameters.

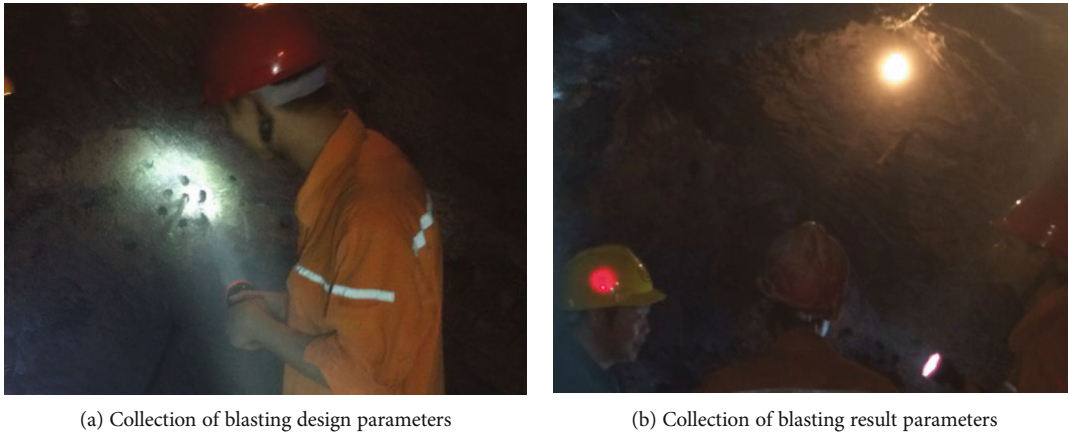To ensure the richness and source reliability of tunneling and blasting data, the new system has collected 594

(a) Collection of blasting design parameters

(b) Collection of blasting result parameters

FIGURE 10: Collection of engineering site parameters.

4	Sizhuang gold mine
5	Xincheng gold mine
6	Jiaojia gold mine
7	Wangershan gold mine

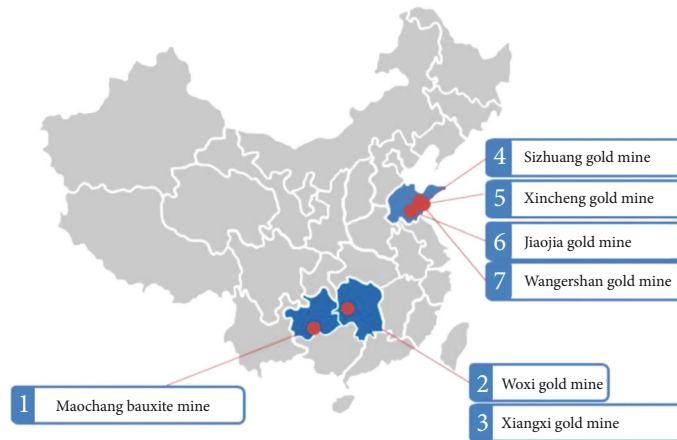| 1 | Maochang bauxite mine |

| 2 | Woxi gold mine |
| 3 | Xiangxi gold mine |

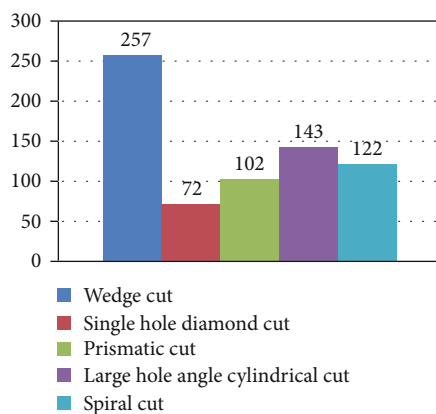FIGURE 11: Data source and data distribution of tunnel blasting in the new system.

FIGURE 12: Number of cases under various cutting schemes.

tunneling blasting cases from 7 mines (mining areas) and 43 different roadways through field tests and case collection schemes for different cutting plans. For cases, Figure 11 shows the distribution of data sources in the new system, and Figure 12 shows the number of cases under various cutting schemes.

4. Application of Intelligent Design System for Mine Tunnel Blasting Based on Database

Briefly show the practical application of intelligent systems.

Take the needs of an actual project as an example. Table 4 is the search parameter of the application example, which adopts the intelligent search method, and the default values are used for other values without specific values. The search interface is shown in Figure 13, and Figure 14 shows the corresponding output results.

It can be found from Figure 15 that through data search, 6 search results that meet the relevance calculation requirements are selected from the existing database files. Among them, the search results of No. 1 and No. 2 have a single parameter of 100% relevance. Figure 14 shows a schematic diagram of the specific blasting parameters and blasthole layout scheme numbered 1 in the search results. It can be found from the figure that the search results meet the search requirements.

TABLE 4: Input parameters.

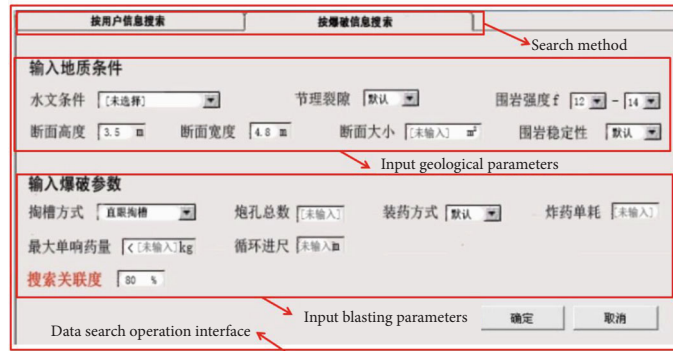| Input parameters	Tunnel height/m	Tunnel width/m	Surrounding rock f value	Cycle footage/m	Relativity/%
Value	3.5	4.8	12-14	>1.6	80

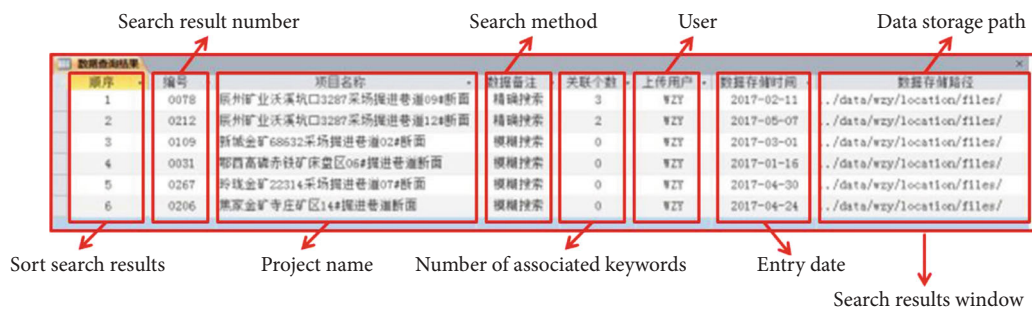FIGURE 13: The search interface using intelligent search.

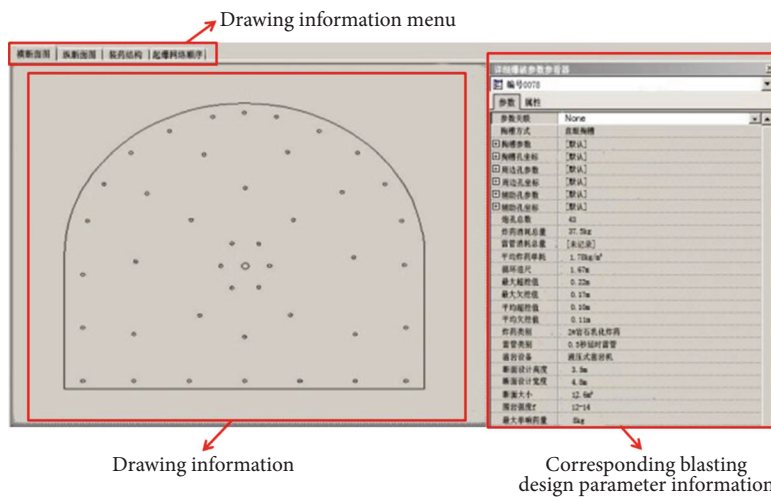FIGURE 14: The output of the fuzzy search.

FIGURE 15: Blasting parameter table and blasting hole layout.

5. Conclusion

Aiming at the problems of the intelligent design system for blasting, starting from the key technology of the database, the research and development of the intelligent design system for tunnel blasting are carried out. This paper expounds the core problems in the development of an intelligent tunnel blasting design system based on database technology and proposes specific solutions:

(1) The database of the new system adopts a central database system. At the same time, to ensure the synchronization and sharing of data, different user rights are designed

(2) According to the characteristics of blasting design and parameters, select appropriate blasting design parameters and related data. Combining relational database theory, the database structure, and data table structure suitable for roadway blasting design are obtained, and each database table is created

(3) Use the T-S fuzzy neural network model to determine the intelligent data search rules of the database

Finally, using Oracle as the database development platform, VB.NET as the system front-end and search rule development platform, and MFC and ADO as the development technology, the tunnel blasting intelligent design system was realized. Through this system, users can conduct unified management, search, and design of data in the tunnel blasting design process.

Data Availability

All data generated or analyzed during this study are included in this article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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