DESIGN AND CONSTRUCTION OF A GIS-BASED DATABASE FOR MANAGING LANDSLIDES IN MINING AREA

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ABSTRACT:

Landslides caused by mining are seriously affecting the construction and sustainable development of mining area. With the characteristics of multi-resource, multi-format, multi-theme and large storage capacity, mining landslide data is difficult to be managed effectively and applied to the evaluation, forecast, prevention and treatment of landsides. Based on mechanism of landslides in mining areas and GIS technology, we analyzed the data in mining area landslide database on different aspects. Landslides and other related objects in mining area were abstracted to relational models by conceptual design, logical design and physical design. A new unique coding method was present according to current specifications and the features of mining areas. Then, we built a GIS-based mining area landslide database using Oracle and ArcSDE. Through program implementation and an experiment, the results shows that the database with rich content is well-structured, satisfying the users who manage mining area landslide information or collect data in the field.

1. INTRODUCTION

The acceleration of modernization in China increases mining in recent decades. Under the influence of open-pit mining, underground mining or other engineering construction, landslide hazard in some mining area becomes increasingly aggravated, making a great amount of landslide data accumulated. In the traditional data management, the data acquisition and updating cycle is long, making the data can not be timely and effectively transformed into information and be shared. Meanwhile, the development of computer technology and spatial technology make it possible to get more and more mining area landslide data of multi-resource, multi-format, multi-theme and large storage capacity. How to manage the data effectively and apply them to the evaluation, forecast, prevention and treatment of landsides in mining area has become a bottleneck to deal with.

GIS started from 1960s, has been applied to the research of landslides for its advantages on data management, visual representation, spatial analysis, virtual reality and integration with decision support system. According to Xie (Xie, 2003), a 3D landslide assessment model was presented and a Grid-based landslide assessment system named 3DSLOPEGIS was developed based on a landslide spatial database. Ulrich Kamp et al developed a spatial database using ASTER satellite imagery and GIS technology to analyze the relationship between earthquakes and landslides in Kashmir earthquake region (Ulrich, 2005). A multi-method approach for the assessment of the stability of natural slopes and landslide hazard mapping was applied to the Dakar coastal region (Fall, 2006). Pece V. Gorsevski et al developed a Spatial-Temporal database model by grid tools of GIS to represent the uncertainty and variability of parameters which caused the landside in Pete King area. (Gorsevski, 2006).

GIS is playing an important role in landslide assessment and forecast, and the construction of GIS-based landslide database is the most foundational part. In this paper we shall discuss how to design and construct a GIS-based mining area landslide database to support data acquisition, information management, mapping and hazard analysis of mining area landslides.

2. GENERAL PLAN OF DATABASE CONSTRUCTION

In order to accelerate the informatization of mining area landslide management, users of the GIS-based mining area landslide database are people who collect landslide data in the field with GPS and PDA, who operate landslide data by desktop applications, who evaluate and forecast landslide stability and who view landslide data comprehensively and make decisions in an effective way.

According to specific demands of different users, we abstracted mining area landslides from the real world to the information world and the machine world by the optimal data model, and turned the objects to operational data. Data in the database should have small redundancy and stable structures during operation, can be shared, expanded and refreshed by users and can be independent from application programs (Li, 2007). Aiming at this target, we evaluated and optimized the database by physical implementation and application running. As shown in Figure 1, owing to abundant spatial data in the database, the theories and technologies of GIS were used during almost the whole process of design and construction of the database, which included data analysis, conceptual design, logical design, physical design, physical implementation and application running.

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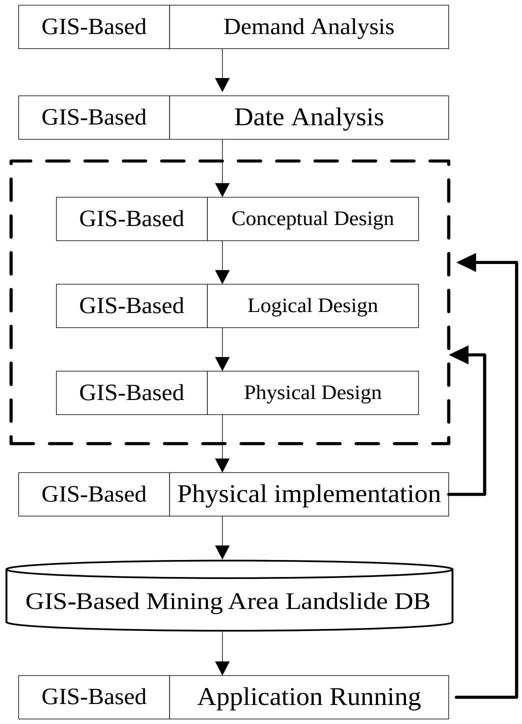

Figure 1. The general plan of database construction

3. DATA ANALYSIS

3.1 Data Content

Data is the blood of a database system, having its cost accounting for 80% of the total cost. It is necessary to analyze the data related to mining area landslides comprehensively and scientifically on the basis of landslide mechanism and the features of mining areas so as to abstract mining area landslides in a reasonable way.

Hazard is the result of a combination of factors, which can be regrouped into breeding environment, inducing factors and bearing body (Song, 2008). For mining area landslides, breeding environment which is quasi-static, contributes to landslide susceptibility and contains foundational geographical environment (terrain, landscape, hydrology，vegetation，etc.) and various geological environment (stratum, geological structure, under water, mechanical parameters for rock and soil, etc.) of the mining area where landslides happen or will happen (Dai, 2002). Inducing factors which reflect the basis of material and energy of landslides, are dynamic variables such as rainfall, earthquakes and mining, tending to trigger landslides in mining areas of a given landslide susceptibility. Bearing body, which reflects vulnerability of the mining area once landslides happen, contains objects that breeding environment and inducing factors act on. Since the above-mentioned factors are various in different mining areas, we should collect landslide data required as comprehensive as possible according to the features of mining area to express landslides sufficiently and satisfy users' daily operation and analysis. Figure 2 shows the data content in mining area landslide database.

In terms of data format, these data can be divided into vector data, raster data, text and other multimedia data. Vector data, that is digital line graph (DLG), reflects the distribution of mining area landslides or their effect factors by points, lines or polygons. Raster data consists of multi-source remote sensing images, digital raster graphs (DRG) and digital terrain models (DTM). Text data is written records accumulated by mining area landslide information collecting of relevant departments. In addition to the above three data, multimedia data also include pictures (photos of mining areas where landslides happen, profile plans of landslides, result charts of landslide stability analysis, etc.) , audios(hazard reports, warning notices, etc.) and videos (animation of landslides, etc.). Vector data and raster data constitute spatial data in mining area landslide database, while text data and other multimedia data constitute attribute data.

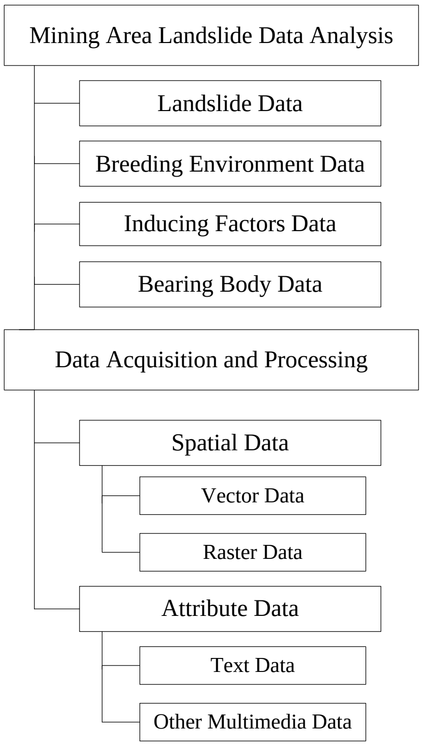

Figure 2. The data content in mining area landslide database

3.2 Data Acquisition and Processing:

We acquired and processed mining area landslide data in different ways according to their different data format.

Vector data was acquired and processed by the following ways:
(ⅰ) scanning and vectoring the accumulated maps of mining area landslides and their effect factors, among which error checking, topology processing, sheet splicing and projection transformation were important;
(ⅱ) creating and editing features on existing layers according to the result of mining area landslide field collecting based on GPS and PDA;
(ⅲ)accepting coordination values of GPS- equipped control stations which were set up on landslides and then representing them on a layer, so as to simulate the motion of landslides dynamically and even forecast the trend of landslides.

Multi-source remote sensing images were acquired by various receivers and stored into database after a series of image pre-processing, such as correction, registering, mosaic, clipping and so on. The DRG were raster-formed graphs of paper maps. DTM were obtained from data of other formats by format conversion, spatial analysis, 3D Analysis and other GIS tools. Some software, such as ArcGIS, Envi, Erdas, were used during spatial data processing.

We get attribute data not only from collecting and entering historical statistics of mining area landslides, but also from creating and editing records on basis of field collecting and landslide analysis.

3.3 Data Organization:

In view of so much spatial data in mining area landslide database, we adopted the top-down physical structure–"Project->Base->File->Layer->Feature" in the database combining the data management concept of GIS. Figure 3 shows the physical structure we adopted.

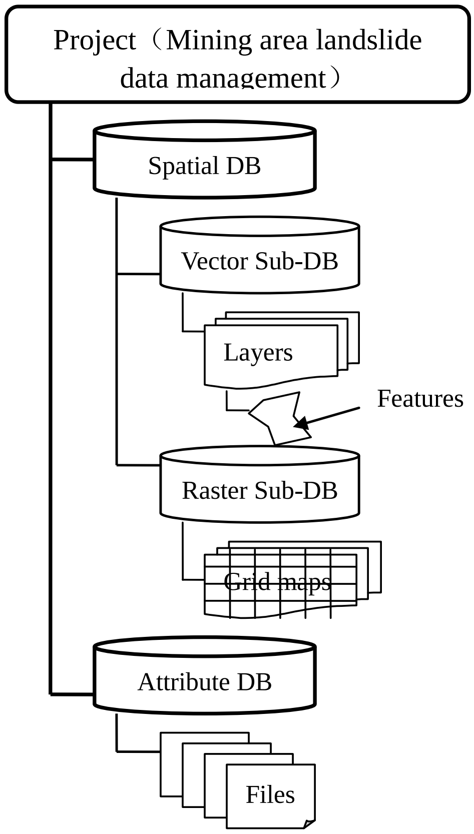

Figure 3. Data organization of mining area landslide database

As shown in Figure 3, a "project", which is the most top-level object of landslide information management in a certain mining area, is a collection of all kinds of data (Zhang, 2001). That means only one project can be built for a mining area. A project contains several bases of different types. Under the control of "project", a "base" is a collection of "files" because of their same data format or logic applications. Hierarchy is a property of bases, that is, a base can consist of several sub-bases. According to different data formats, the mining area landslide database can be divided into spatial database and attribute database, while the spatial database can be divided into vector database and raster database.

A "file", which can be a picture, a text document, a layer or a remote sensing image, is the fundamental unit of data to be managed by applications. "Layer" and "feature" are intended for vector data. In vector database, the data range of a "layer" is the same with that of a "file". Layers express the distribution of landslides and their factors. A "feature" is the smallest data unit, expressing an object by a point, a line or a polygon.

4. DATABASE DESIGN

4.1 Conceptual Design

Conceptual design, which is often considered as the key to the success of a database, abstracts research objects from the real world to the information world. In the conceptual design of mining area landslide database, we synthesized and described mining area landslides and other objects by standing on different users so as to meet their demands.

E-R (Entity-Relation) method, which is often used in conceptual design, abstracted a collection of landslides or other objects to an "entity", a relationship between different objects to a "relation" and a feature of objects to a "property". The conceptual design of mining area landslide database using E-R method included the following two steps:
(i) designing partial E-R models. Figure 4 shows the partial E-R model of mining area landslides, control stations and the relationship between them.
(ii) synthesizing all the partial E-R models to an overall E-R model.

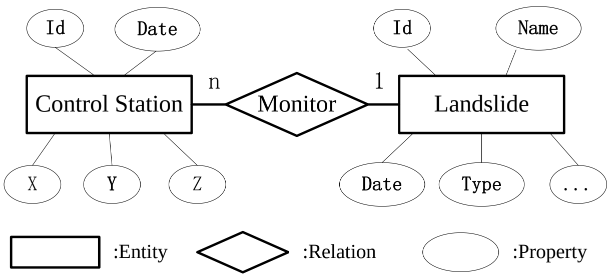

Figure 4. The partial E-R model of mining area landslides and control stations

4.2 Logical Design

At present, the common data models in the field of database are network model, hierarchical model, relational model and object-oriented model. Among the characteristics of simple and flexible structures, editing and updating data conveniently and easy to be maintained, relational model owes its greatest advantage to consistency of description. Relational model is not only the most commonly used data model in database, but also an effective data organization approach to build relationships between spatial data and attribute data. Most of GIS attribute data are organized in relational data models, and even some systems adopt relational database management system to manage spatial data (Zhang, 2007). Therefore, we adopted relational mode in the GIS-based mining area landslide database.

4.2.1 Relational Model Deriving: Since the mining landslide E-R models were independent of any specific data mode, we turned them into logical structures equivalent to relational models firstly. An entity or relation was expressed as a relation table, and their properties were expressed as attributes of relational tables, namely “fields”. As a result, mining area landslides and other objects were abstracted to the machine world.

The relational model corresponding to the partial E-R model of mining area landslides and control stations are:
Landslide: (LSId, LSName, LSDate, LSTye,…)
Control Stations: (CSId, CSDate, CS-x, CS-y, CS-z)
Monitor: (CSId, LSId)

4.2.2 Equalization of Relational Models: The initial relational models we derived seems disordered and confused for the complicated relation between mining area landslides and their breeding environment, inducing factors and bearing body. For example, properties of mining area landslides alone could be expressed as lots of fields in the landslide attribute relational table. Aiming at this issue, we adjusted the relational models by dividing every initial relational table into a group of simpler and more stable relational tables when it was necessary according to the different retrieval frequencies, logical relations and people’s attention of various properties. Then, more logical and orderly relational models were obtained. The process we adjusted the relational models is called equalization of a relational models. It makes a lot of sense to efficiency and security of database systems. Figure 5 shows the relational tables of mining area landslides after equalization.

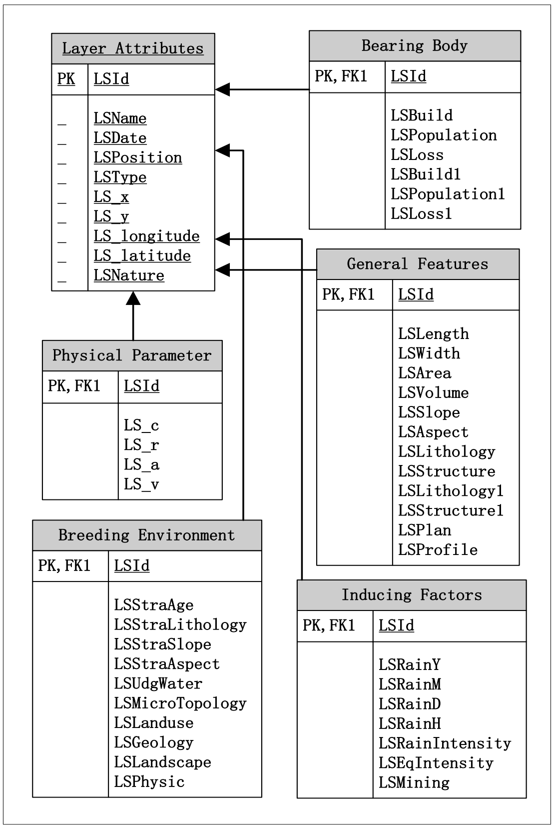

Figure 5. Equalization of the relational model of mining area landslides

As shown in Figure 5, because people care more about basic properties of mining area landslides (name, time of happening, landslide type, and position, etc.), we stored them in the inner layer attribute table, the attributes of which can be retrieved more quickly and conveniently. General features, breeding environment, inducing factors, bearing body and physical parameters stored general properties of mining area landslides in external tables. They were regrouped by the different logical relations between mining area landslides and other objects. The table named general features stored attributes reflecting the development of landslides. The table named physical parameters stored mechanical parameters of stratum which are often retrieved and used in landslide stability assessment on the basis of mechanics (Wu, 2006). Among all the attribute tables of mining area landslides, the table named layer attributes takes the uniform code (LSId) as principal key to define the existence and uniqueness of a mining area landslide, while other tables take it as foreign key. Then, all the attributes established connections with the feature in the mining area layer.

4.2.3 Uniform Coding and Indexing: In order to realize data sharing and improve retrieval efficiency, we created indexes in the mining area landslide database. As the premise, uniform coding for each data organization structure were considered inevitably.

Actually, there are several uniform coding specifications for geological hazard spatial database at hand. But all of them aren’t customized specially for mining area, and cannot organize and manage all the data of a mining area in a big collection. In additional, by these specifications, the spatial characteristics of spatial data and attachment relationships of different data organizations cannot be reflected. Therefore, by referring to and modifying the specifications, we finished uniform coding for mining area landslide database, containing semantic consistency and rich descriptions. Taking “#” as an Arabic numeral and “□” as a letter, uniform coding for “project”, “layer”, “feature” will be shown in Figure 6-8.

(ⅰ)As the top-object in the database, a project takes its Mine Number which is recorded in *Mineral Reserves Registration Statement* as its uniform code. The Mine Number consists of 9 digits. The first 6 digits is the code for the administrative division where the mine located and can be determined on the basis of *GBPT2260 – 2002*, and the last three is the mine’s sequence number in its administrative division. The structure of the uniform code of a project is shown in Figure 6.

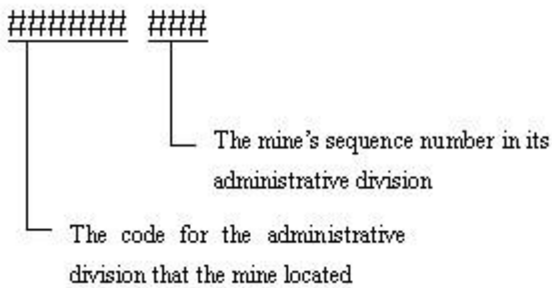

Figure 6. Uniform code of a project

(ⅱ) The uniform code of a layer is made up of the uniform code of the project the layer attached to and its own codes. The structure of the uniform code of a layer is shown in Figure 7.

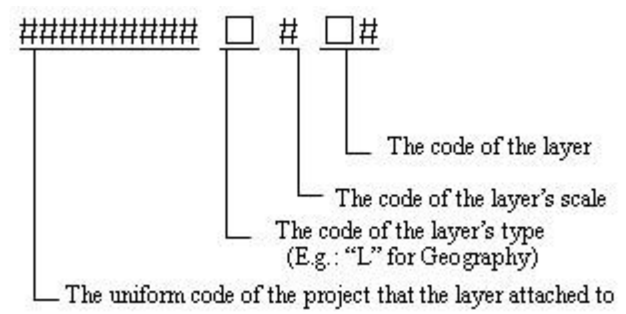

Figure 7． Uniform code of a layer

The codes of the layer's type and the layer are determined on the basis of *GB/T13923-92*, which is customized for geological hazard spatial database and accepted by lots of people. The available codes of the layer's scale are: "A"-1:1000000, "B"-1:500000, "C"-1:250000, "D"-1:100000，"E"-1:50000，"F"-1:25000，"G"-1:10000，"R"-1:200000.

(iii) The uniform code of a feature is made up of the uniform code of the layer that the feature attached to and its own code, which is a 4 digits generated by its entering order to the database. The structure of the uniform code of a feature is shown in Figure 8.

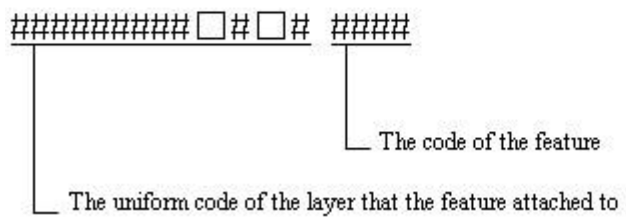

Figure 8． Uniform code of a feature

4.3 Physical Design

Since relational model was adopted in mining area landslide database, a relational database system should be chosen to manage data. We chose Oracle as mining area landslide data management platform considering its characteristics including: (ⅰ) supporting high-performance multi-user transaction; (ⅱ) supporting mass multi-media data, such as binary graphics, audios, videos and multidimensional data; (ⅲ) security and integrity; (ⅳ) supporting distributed-database and distributed-transaction ; (ⅴ) portability, compatibility and connect ability.

In the case of spatial data management, ArcSDE, which is a middleware between application and relational database system, can act as the server to access multi-user geodatabase stored in relational database system and offer an open interface. Considering ArcSDE's advantages of mass data storage, multi-user concurrent access, version management, long transaction, we chose ArcSDE as spatial data management engine in mining area landslide database, storing and managing spatial data and attribute data uniformly and efficiently.

5. DATABASE IMPLEMENTATION AND RUNNING

The implementation of mining area landslide database can be divided into two sections: data loading and programs writing and debugging (Wang, 2004). According to the logical structure of the mining area landslide, we built relational tables in Oracle, and realized the links between the tables as well as the links between attribute records and features by setting up primary keys and foreign keys. In order to facilitate data input, output and management, a mining area landslide database management system was developed by ArcEngine and C#. In addition, a GPS-base mining area landslide field data collecting system running on PDA，through which we can create and edit data in the database, was developed by ArcGIS Server and C#. We carried out an experiment in Yanzhou mining area which is located in Jining, Shandong Province, China. The result was ideal, and showed that the mining area landslide database we designed and constructed met the users who collected data in the field.

6. CONCLUSION

In this paper, the process we designed and constructed the mining area landslide database was discussed. We analyzed the data of the mining area landslide database on aspects of content, acquisition and organization structure on the basis of landside mechanism and GIS technology. By database design, landslides and other objects in mining areas were abstracted from the real world to the machine world and reasonable relational models were obtained. A unique coding method for mining area landslide was present according to current specifications and the features of mining areas. We built the mining area database by Oracle and ArcSDE. The database we designed and constructed was proved to be feasible and satisfy the users who manage mining area landslide information and collect data in the field by application running. In the following work, we will focus on the research and implementation of mining area landslide stability assessment model so as to adjust and maintain the database and satisfy the users who analyze and make decisions on mining area landslides.

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