DESIGN OF SPATIO-TEMPORAL DATABASE SYSTEM FOR MINING LAND

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ABSTRACT:

The principle and method are given to build spatio-temporal database for mining land via analyzing the data storage modes in reality database and history database. Based on building the spatio-temporal data model of mining land, a Spatio-temperl Database System for Mining Land is developed with using the visual programming language Visual Basic and components ArcGIS Engine. The reality database and history database are established with Geodatabase data model, and marking the time, in which the recorder date is judged to reproduce the situation of land use in different historical periods. There are nine modules in the system as follows: startup, control of layers, editing of data, storage of date, query, recurring of history, statistic, analysis and overlay. The realization of the system mainly related to spatio-temporal land-use data's updates, historical data query, historical recurrence, statistical analysis, overlay analysis etc. As a result, the system is for the evolution of land use in mining area, with introducing time attribute to realize data updating and reality database - history database operating. As a sample, a mine area is taken to build a spatio-temporal database, whose data are analyzed to find the change of the mining-land use structure.

1. INTRODUCTION

Spatio-temporal database is the warehouse to store all the data TGIS needed, on whom any data operation and data analysis must be based (Ying, 2002). Spatio-temporal database system is the important technical support for TGIS, being the key and premise to the whole development of that (Xu, 2005). Data organization and management of mining land have to base on GIS and spatio-temporal database technology, and take from secondary development with considering the feature of land evolvement, in order that data are easy to be operation, with intuitive and friendly interface show as much as possible to meet user requirements.

2. NEEDS ANALYSIS TO SPATIO-TEMPORAL DATABASE OF MINING LAND

The needs analysis to spatio-temporal database system of mining land, aim to determine the external requirements of the database,and with data flow diagram,data dictionary and other form to determine the information contents for database and data-processing requirements for users.

The main contents of needs analysis to spatio-temporal database of mining land are as follows.

(1) To analyze the necessary data of mining land evolution in order to generate data flow diagram shown as figure 1.

(2) To find out the inter-relationships of the required data types mining land evolement as well as among data.

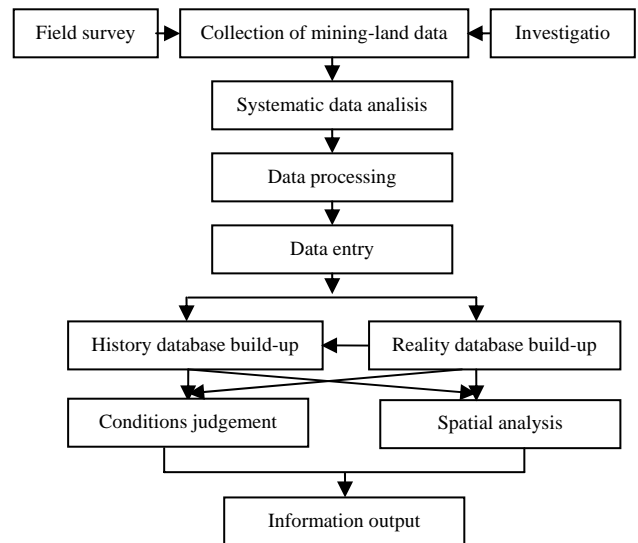(3) To know the overall requirements of the database and the system.

Fig. 1 Data flow chart of mine area land resource management information system

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3. SPATIO-TEMPORAL DATABASE DESIGN OF MINING LAND

3.1 The basic requirements for the design of spatio-temporal database

(1) To definite large amounts of data with non-redundant structure, and enable them to be used by different users according to the needs.
(2) When data elements are inserted, modified and deleted, their structure, mutual relations and affiliation relationship should remain unchanged.
(3) Application programs do not rely on data organization and storage location of the database, which is called data independent. Here refers to different application programs can access the data in database accorging to be required structure. Meanwhile, the existing application programs need not to be rewritten or modified when the data changes.
(4) To ensure the data's accuracy, effectiveness and compatibility in logical sense.
(5) To facilitate the users to write modify, add and delete data independently.
(6) To facilitate to query and reduce the search times in the database.

3.2 Main task to design spatio-temporal database of mining land

The main task to design spatio-temporal database of mining land is to re-classify and organize the spatio-temporal data, and describe the logical structure of the database from the user point of view. The logic design for the spatio-temporal database in the ground-state amendments model with improvement based on Geodatabase, are usually in three steps: at first, systematic data classification including vector and raster one; secondly, organization of graghic layers information; thirdly, selection of attribute information.

Temporal information in terms of land use dynamic monitoring is essential as each geographical elements must have their own temporal attributes. Through analysis to the graphic information and attribute one in different periods, the dynamic evolution of land use can be induced. In Geodatabase, the graphics data and attribute ones are stored in the relational database uniformly, with each geographical elements as a tuple of a table. We can store the elements of geographical information as a tuple of the field in relational database.

Adopting the ground-state amendments model with improvement based on Geodatabase, the reality database and history database are established with Geodatabase data model, and marking the time, in which the recorder date is judged to reproduce the situation of land use in different historical periods. As a result, the design of spatio-temporal database is mainly that of history database and reality database in fact.

4. SKETCH OF SPATIO-TEMPORAL DATABASE BUILD-UP

4.1 Data table design of history database and reality database

GIS is essentially the approximate simulation of the objective world, whose ideal state should be that reflects the geographical world as accurately as possible, at the same time with less data,

and easy to get necessary information and laws (Luo, 2001). The database build-up needs to consider the temporal cohesion intensity and spatio-attribute one (Li, 2003). To mining-land use change, the types changes are mainly operated, being frequent with a larger quantity, whose historical operation is more frequently when taking spatio-temporal queries. Therefore, real data and historical data should be stored at best in the same data set. Its organizational form shows as table 1, 2.

ObjectID	Shape	From-Date	Type	CN-Type	Shape_Length	SHAPE-Area
ObiectID	Poly-gon	DATE	Short integer	Text	Double	Double

Table 1 Reality database table of spatio-temporal database

Object-ID	Shape	From-Date	ToDate	Type	CN-Type	Shape_Length	SHAPE_Area
Obiect-ID	Poly-gon	DATE	DATE	Short integer	Text	Double	Double

Table 2 history database table of spatio-temporal database

and does not allow modification. Shape discribes for the features of ground objects, including Line, Mulitline, Mulitpoint, Point and Polygon in ArcGIS, a total of five kinds, which are automatically added by the system. Shape_Length represents perimeter for the shape property line or Polygon, with the attributes being automatically added. Shape_Area represents area for Polygon attribute, being automatically added. The land use types in mining area are mainly in area attibute, with shape polygon. FromDate expresses effective beginning and ending time for objects, whose data type is date one. Type attribute is for the sub-class code. CNType is for use type of land block.

All the changed objects in the system are recorded in table 2, in which a record corresponds with a changed object. The meaning of the field ToDate in the table is the invalid time of objects,to which from FromDate is the life period of objects. The ID of object in history database table is unified to that in reality one in order to keep its uniqueness current or historical object.That is to say,any object ID can not be allowed to appear in the reality database and history one at the same time,or else the unification of the systematic data will be destroyed. If there happens a change in an object even attribute, it should be deleted from the reality database, at the same time being added to history database when it will change but there is no change at the moment. Meanwhile, the change time should be recorded, being this time that the object dissappears in reality database and becomes historical data, to the record corresponding to the data item of ToDate in the history database table, together with which the data item of Fromdate inherited from the reality database constitute commonly the life period of the object.

Spatio-attribute cohesion intensity refers the integration degree of spatial information and attribute one in applications. Object is always in the process of changing, whose change involves time, space and attribute ones. Geodatabase stored spatial information and attribute one uniformly to a relational database in order to avoid the association between spatial information and attribute one (Song, 2004).

For enhancing the query speed and reducing storage space, we unify farmland, woodland, subsided land, construction sites and other land-use types, a total of six, to land as a whole, which is divided followly into six subtypes of land. Such a design is consistently in line with people's thinking, also can improve the

query speed. Therefore, TYPE is set to short integer type in above historical and current status table. Design of subtype shows as table 3.

If each type of land use is taken as a layer, there are six layers in in reality database, similarly six ones in the history database. To query needs to search back and forth among the 12 layers. However, when the above mentioned six kinds of land-use type are taken as a subtype of land, the history database and reality one have only one layer respectively, so that the inquiry can be done by searching between only two layers with greatly higher speed.

1	2	3	4	5	6
farmland	Subsided land	woodland	Construction sites	Water area	Other

Table 3 Table of subtype

4.2 Differences of the build-up mode between history database and reality database

The build-up mode of history database is roughly the same as reality database, having only two differences as follows.
(1) The elements type in history database has more a time attribute Todate.
(2) The data source of history database is different, directly from reality database, but the data in reality database sources from original digital data or later edited ones.

5. GENERAL DESIGN OF SPATIO-TEMPORAL DATABASE SYSTEM FOR MINING LAND

5.1 System overview

The development of mining-land spatio-temporal database system mainly deals with spatio-temporal data update, historical data query, history recurrence, statistical analysis, overlay analysis and other functions for mining-land use. Based on related theories and ideas, this system takes time attribute for evolution of mining-land use so as to realize data updating and operation between history database and reality database.

The update and query system for spatio-temporal data of mining land, collecting the data of mining-land's evolution course and storing them in GIS database. It can put the data in for correlating, analyzing and displaying, in order to provide a wide range of spatial and dynamic land information, and services for land remediation of mining area.

The key technology of the update and query system for spatio-temporal data of mining land includes GIS technology, spatio-temporal database build-up, data storage and retrieval, and so on, whose build-up will provide technical supporting to dynamic monitoring and real-time management for mining land.

5.2 Design principles of the system

The management of mining-land spatio-temporal data is a complex and highly integrated systematic engineering. The system should be designed to strictly follow the norms of software engineering, and ensured to have scientific and rational structure framework, being optimized and highly efficient system. In the premise of meeting user needs, the system should raise its performance indicators to maximization,

whose general design abides by following principles: practicability, reliability, convenience, adaptability.

5.3 System targets

Mining-land use data have a large quantity of information and update frequently, whose historical data should be preserved as important archives. If these data are managed by GIS, the GIS is typical TGIS, in which the mining land and its use change are modeling. Mining-land use data are spatio-temporal ones, not only having spatial feature, but also whose its shape and attibute have strong temporal characteristics. To explore the change types of mining-land use is an important prerequisite to establish update mechanism.

Based on the analysis to the basic types and characteristics of mining-land use evolution, adopting the theories of the ground-state amendment and Geodatabase modeling, with traditional relational database Access, this paper designs amd realizes a data-update management and spatio-temporal query system for mining-land use.

5.4 System development process

Based on system design goals, with the methodology principle of information system development, the system is buildup. The development process is as follows.
(1) On the basis of full investigation and analysis, the feasibility and strategy are analyzed and studied.
(2) System development goals making, system scale determining, general plan carrying out.
(3) Through the analysis to business, function, data and environment, the system structure is put forward. Then the design of interface, classification coding and environment are done.
(4) The data source is determined to design database. According to systematic requirements and data analysis results, the data structure is definited, mainly including that of all data tables, primary cuttons, as well as the linkages between the data tables.
(5) System analysis and design. Based on data analysis and data structure, the functions that can and sould be realized are discussed in order to carry out systematic integrated design, mainly including functional analysis, data or affairs processes, modules dividing, etc.
(6) Codes writing. Systematic functions are developed, involving functional modules programme writing, compiling and debuging.
(7) Operation and maintenance. In accordance with the design and the actual development, the system is tested in a full range such as functional testing, abnormal testing, etc.

5.5 System interface design

A nice user interface is an important factor to ensure the normal operation of the system, which affects the approach of users to the system and then the system function to play. The interface design, therefore, generally abides by the following principles.
(1) Adopted the idea of user-oriented, with character menu prompt, the operation is simple and practical.
(2) It make use of Windows style to design various types of dialog boxes and icons so as to achieve highly interactive.
(3) Standardize the menu to be convenient for user's use and memory.
(4) To provide guidance and assistance function to running.
To pursue a friendly user interface, the system applies ActiveBar control in the development process, which is an

essential ActiveX control to user interface design. That can be used to design personalized menu similar to Word, self-definiting dialog box, shortcut buttons bar like Outlook, and control options page as Delphi.

This system brings some orders together into one toolbar, whose functions are similar to each other, or which should coordinate each other to complete a task. It has six toolbars such as for mapping tools bar, graphic one, standard one, function one, editing one and mapping layout one, in which the last one serves for the mapping view window. These toolbars are similar to those in Word, being able to park under menus, also be pulled out with mouse. They can control their visibility by the toolbar under menu view window, also through click the right mouse button.

The bottom window of the system is the status bar, which can display display the current operation of the mouse, also show the location information of the mouse with the form of X and Y. If the distance surveying order of the mapping toolbar is used, the total length of line and the length of the last paragraph will be showed in the status bar.

The left side of the systematic window is the layer control window and eagle eye. After system restarts, the systematic interface shows as figure 2, with mapping toolbar as figure 3 and standard toolbar as figure 4.
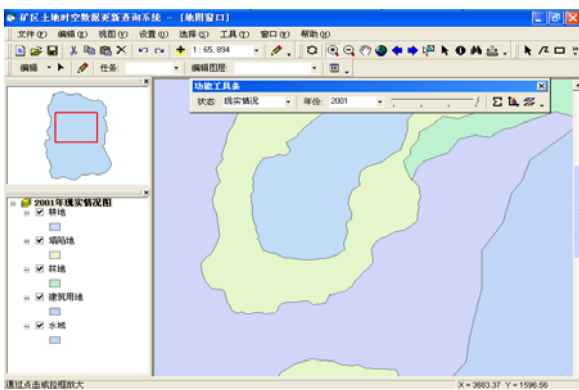

Fig. 2 Interface of system
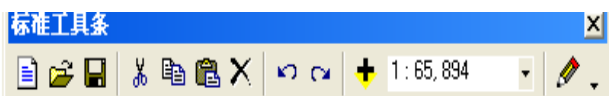

Fig.3 Mapping toolbar

Fig.4 Standard toolbar

5.6 Main modules of the system

The system frame shows as figure 5, having a total of 8 modules, including files operating, view management, editing, query, statistics, overlay analysis, history reproduce and output.
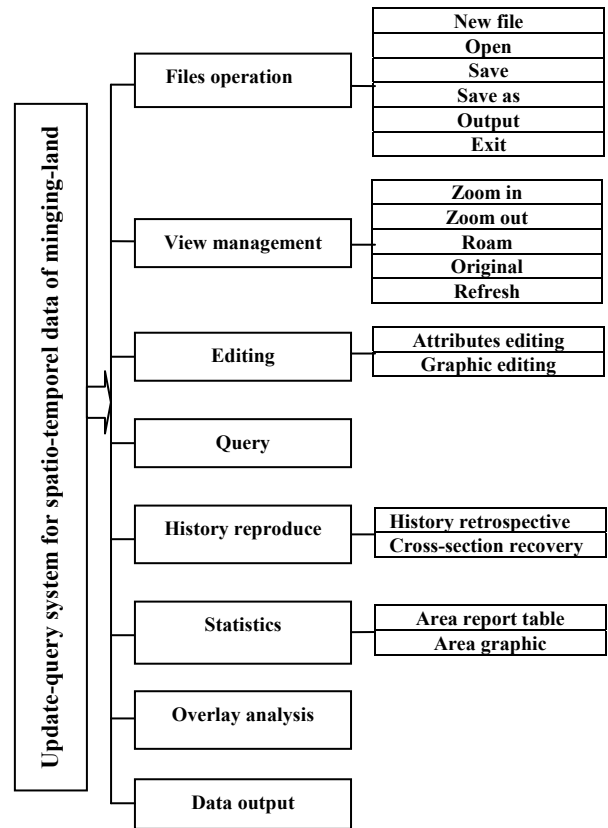

Fig .5 Function frame chart of system

6.   EXAMPLE ANALYSIS TO STRUCTURAL CHANGES OF MINING-LAND USE

The statistical function of the system is applied to attain the land use area of various types in different periods from 1972 to 2001. After collating and calculating, the results are shown in table 4. From the table, the change of the mining-land use structure can be seen large, mainly in the construction site, subsided land, woodland and other types of lands, but little change in farmland and waters. For the percentage and absolute amount of area change in the studied area, the subsided lands increase in the year-on-year, while the woodland reduce at same time.

According to the analysis of table 4, some conclusions can be drawn as follows.
(1) Farmland, woodland and construction area decreased year by year, while the subsided land and waters area increased.
(2) For the rates or the range of change,

The subsided land > construction land > woodland> water area > farmland

Therefore, change of the subsided land, construction one and woodland is stronger, while that of water area and farmland more ease.

(3) The subsided land grows out of nothing, with little change in the area of farmland, while woodland area reduces more.

Type	Area 1972		Area 1979		Area 1991		Area 2001		1972-1979	1979-1991	1991-2001
	m^2	%	m^2	%	m^2	%	m^2	%	Change m^2	Change m^2	Change m^2
Farmland	669498.964	44.3	6235812.755	41.2	5921756.213	39.2	6448142.438	42.7	-433686.209	-314056.542	526386.225
Subsided land	0	0	0	0	1138659.164	7.5	2272640.476	15.0	0	1138659.164	1133981.312
Woodland	2147525.03	14.2	2056301.702	13.6	1915828.15	12.7	1486540.639	9.8	-91223.328	-140473.552	-429287.511
Construction	4471812.625	29.6	5033352.141	33.3	4064512.772	26.9	2772640.264	18.3	561539.516	-968839.369	-1291872.508
Water region	1829805.226	12.1	1793985.247	11.9	2077876.578	13.7	2140014.892	14.1	-35819.979	283891.331	62138.314

Table 4 One mining-land use frame and dynamic change in 1972 to 2001

Above is general changes analysis to land use of a coal mine. The following is to analyze the changes in different periods of the mining-land use. The land-use situation in differen periods can be gotten from the history refresh function of the system, shown as figure 6, 7, 8 and 9.

(1)1972-1979. A coal mine began to be built from 1972, and finished all constructions in 1979, as figure 6 and 7. This period is mainly for constructions of the mine. A large number of buildings needs to be built in the course of mine constructing, so construction area increases sharply. Meanwhile, as the buildings locate on farmland, the farmland area reduces accordingly. Therefore, the biggest change of this phase is the increase of construction area, while the reduce of farmland area.
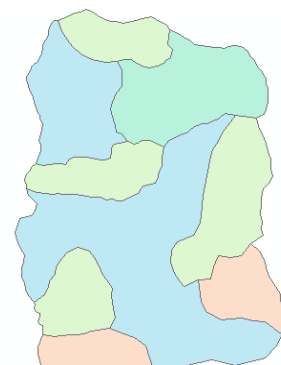
(2) 1979-1991. From 1979 to 1991 as figure 7 and 8, the coal mine was built to produce coal. After coal was mined out, the surface of farmland was destroyed due to collapse from minging, accumulating water in order to form water region. Most of the mining area are farmland, so the subsided land evolved from that. As a result, the increase of subsided land lead to the reduce of farmland. During this period, coal mining mainly concentrated at the center of the mining area, so the subsided land waters mainly concentrated at there at the same time, then proliferated around. In short, the most important changes during this period are the reduction of farmland and construction sites while subsided land area and waters increased dramatically.
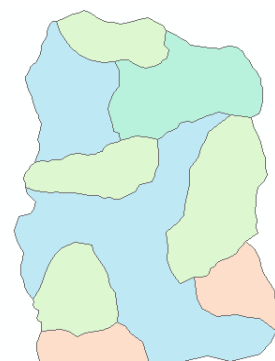
 (3) 1991-2001. As figure 8 and 9, the coal mine's production reached its peak of 500,000 tons in 1992, then decreased accordingly and was only 300,000 tons in 2001. During this period, the mining activities continued, whose difference from the previous period, was changed from the center area to the surrounding. Therefore, the subsided land of this period also proliferated around. The original construction site at the west of the mining area became subsided land after collapse due to mining activities, then was reclaimed wholly to farmland.
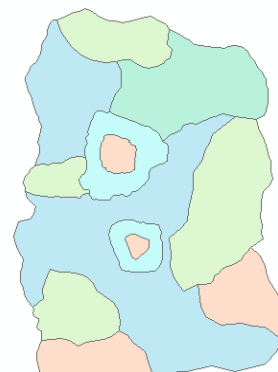
The dynamic rate of change of the mining-land use structure during 1972-2001 is shown in table 5. It can be seen, the subsided land takes a fastest growth in the 10 years between 1991-2001 with average annual growth rate of 7.2 percent, being the first in all types of land-use changes. Meanwhile, the decline in the number of constructions land is the first size in various land-use types to reduce.
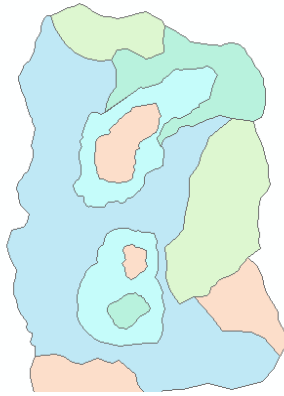

Fig.6 1972 land use chart

Fig.7 1979 land use chart

Fig.8 1991 land use chart

Fig.9 2001 land use chart

7. CONCLUSION

Throgh needs analysis, the basic requirements for the design to spatio-temporal database of mining land are discussed. Based on defining the relevant contents of history databaes and reality one, the history database table and reality one are designed, with the method to build up spatio-temporal database being analyzed and introduced in detail.

The development issues of update-query system for spatio-temporal data of mining land are specifically studied in this paper, including the choice of development methods, systematic general design, the realization of functional modules, systematic technical processes,etc. by applying VB6.0 and ArcGIS Engine as the development tools, an update-query system for spatio-temporal database of mining land is developed. The developed system provides a variety of more complex analysis functions, replaces boring character data with visual images, and provides imagic comparison to the study on evolution of mining land. Besides routine inquiries to spatial information, the system has the functions including overlay analysis, historical refresh,data entry,etc. taking a mining area as an example, its structural changes of land use are analyzed.

Land type	1972－1979		1979－1991		1991－2001	
	General rate of change	Annual change rate	General rate of change	Annual change rate	General rate of change	Annual change rate
Farm	-6.5%	－1%	-5.3%	0.4%	8.1%	0.8%
Subsided					99.6%	7.2%
Wood	-4.2%	-0.6%	-6.8%	-0.6%	-22.4%	-2.5%
Constructio n	12.6%	1.7%	-19.2%	-1.8%	-31.8%	-3.8%
Waters	-2.0%	-0.3%	15.8%	1.2%	3.0%	0.3%

Table 5 Land use frame dynamic change of one coal mine in 1972 to 2001

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