COMPUTER SYSTEM FOR GEOMETRIC MODELING OF GEOLOGIC BODIES AND APPLICATIONS[①]

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ABSTRACT Based on the concept and theory of geologic body geometric modeling, the essential ways and techniques for building computer system of geometric modeling of geologic bodies were presented. The data structures of geologic body geometric modeling, construction of geologic bodies models, geometric operation and entirety properties analyses of geologic bodies were discussed. In addition, the concrete process for automated ore-delineation and automated generation and plotting of exploration profile maps by using these theories and methods were put forward, and some actual application examples were also given.

Key words geologic body data structure mathematical model automatic plotting

1 INTRODUCTION

The models of geometric modeling of geologic bodies bear geometric, topological and attribute information[1]. By means of computer, we can carry out information storage, model construction, geometric calculation and analysis, rendering and plotting of geologic bodies. In fact, without computer, we couldn't build and process any pratcically useful and valuable model of geologic body geometric modeling because of their natural complexity.

2 DATA STRUCTURE OF GEOMETRIC MODELING OF GEOLOGIC BODY

Geometric modeling should be able to describe and analyze complex geometric, topological and attribute informations of all kinds of geologic bodies, so we must, first of all, define valid data structures to express information of geologic bodies to design a computer system of geometric modeling and application of geologic body. In designing the data structures of the system, it is necessary to take the space and time complexity into careful consideration in order to raise the run efficiency.

In the study and development of the Automatic Generating and Plotting System of Geology-survey Maps (GDPS)[2], for the first time, the authors have built the data structures of the geologic bodies geometric modeling, whose structures are based on the extended relation data model for the support of the GDPS system database.

In order to greatly raise the system execution efficiency, we have proposed some new algorithms such as fussy Hash search. We'll relate the data structures describing the information of the geometric models of the geologic bodies by C/C++ format as follows.

2.1 Node (NODE)

A node is a basic geometric element of various geologic bodies (point-like, linear and planar bodies), which expresses a 2-dimensional coordinate point. Every node bears a unique identification number and a pair of coordinates x and y.

```
typedef struct{
long idNode; //identification number of the node
float x; //co-ordinate x
float y; //co-ordinate y
} NODE; //define node data type
```

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2.2 Arc segment(ARC)

An arc segment is a polyline composed of a series of sorted nodes called as node string, whose arc segment has a unique identification number idArc.

```
typedef struct {
long idArc; //identification number
long idNode; //identification number of node making the arc segment
} ARC; //define arc segment data type
```

An arc segment is acturally composed of the records with the same idArc stored continuously in the data table, and the first record is the first node of the arc segment while the last record is the last node.

2.3 Point-like geologic body(PG)

A point-like object bears not only its node (NODE)'s geometric information but also attribute information(e.g. point name, element contents and labels) whose data type APG's definition is different from the concrete geological application.

```
typedef struct {
long idPG; //identification number
long idNode; //node identification
APG apg; //attribute information
} PG; //define data type of point-like geologic body
```

2.4 Planar geologic body(FG)

A planar geologic can be expressed by face block(FACE) and it bears certain attribute characteristics(e.g. number of orebody, grade, area and labels) defined as AFG.

```
typedef struct {
long idFG; //identification number
long idFace; //geometric expression
AFG afg; //attribute information
} FG; //define data type of planar geologic body
```

2.5 Complex geologic body(CG)

A complex geologic body is a complex structural body composed of other geologic bodies (simple point-like, linear, planar geologic bodies and complex geologic bodies), and similarily, it has its own attribute characteristics(ACG) such as name and labels.

```
typedef struct {
long idCG; //identification number of complex geologic body
long idG; //identification number of simple geologic body making CG
AFG afg; //attribute information of complex geologic body
} CG; //define data type of complex geologic body
```

A complex geologic body in the data table is composed of the records with the same idCG.

2.6 Other structures

In carrying on the geometric modeling, analyses and searches of geologic bodies, we may use other structures such as linear geologic bodies, face blocks, geologic bodies labels, down-to-up topological relations, adjacency topological relations and so on. These data structures can be defined and built as the data structures stated above.

3 CONSTRUCTION OF GEOMETRIC MODELING MODELS

3.1 Basic techniques of construction

There are mainly graph theory, set theory, parametric representation, cell decomposition modeling, sweep modeling, constructive solid geometry, boundary modeling and curve frame modeling[4, 5] which can be used to construct the geometric modeling models. Graph theory and set theory are general modeling techniques fitted for regular and irregular objects. Cell decomposition models can be used for the discrete representation of geologic bodies.

3.2 Construction of geologic body model

The models of geologic bodies can be constructed based on geometric, topological and attribute informations which come from raw geological data. The basic processes or steps of constructing geologic body models are as follows: (1) to arrange and classify the geological raw data; (2) to build the data base of the geological raw data; (3) to extract the raw data of the research range and targets(e. g. profiles) ; (4) to select coordinate system for the research targets, and to transform the extracted raw data coordinates into the coordinates of the research targets (coordinate transformation) ; (5) to search the geologic bodies on the top-to-down classification of geologic bodies and extract the data of the geologic body found; (6) to decompose the extracted data into geometric data and attribute data; (7) to construct the geometric information (e. g. coordinates, nodes and strings) from the decomposed data on geological rules; (8) to build the topological information of the found geologic body and its all daughter geologic bodies; (9) to acquire(e. g. name) and calculate(e. g. area and grade) the attribute information of the geologic body; (10) to store the identification number, geometric information, topological information and attribute information in the data base of the geometric modeling of the geologic bodies on the data structures related above; (11) to go to (5) until all geologic bodies have been searched and processed.

3.3 Modeling techniques of some typical geologic bodies

It is the most difficult to build the geometric and topological information of the geologic bodies in the construction processes stated above because the information is relative to the concrete types and geological rules of the geologic bodies. We relate modeling techniques of some typical geologic bodies in the following.

(1) Drill point

On the level profile maps and generalized geologic maps, a drill point is the open point or level-cutting point of the drill hole. The modeling steps are: to calculate the horizontal coordinates of the drill points → to generate the node information (coordinates and identification number) and write them into the node table → to generate the drill point information (identification number of the point-like geologic body, identification number of the node, labels, drill number, etc.) → to write the drill point information into the point geologic body table.

(2) Trench

A trench is a linear geologic body in the level profile. The raw data of the trenches are trench number, survey data, logging data and sampling data. The geologic shape of a trench is completely controlled by the traverse survey points of the trench, and the point string defines the trench' s geometric model, so it is necessary to build the node string in sequence of the measuring points. The steps are: to calculate and transform the survey points coordinates → to generate the survey nodes → to generate the node string and the arc entity of the trench and write the arc information into the arc table → to generate the trench information(the linear body identification number, daughter arcs, trench number and labels) → to write the information into the linear geologic body table.

(3) Orebody

An orebody is a planar geologic body which is composed of a series of arc segments with one' s tail linked to another' s head.

The modeling steps of an orebody are: to unify raw data → to calculate and transform the coordinates of the ore bodies limitation points → to sort the control points by limitation line → to calculate the real and image intersection points of the limitation lines → to generate the control nodes, interpolation nodes and shared nodes → to generate the orebody information (identification numbers of the planar geologic body and the face block, orebody number, area, grade, etc.) .

(4) Orebelt

In some mines, a number of bodies in a limited range are defined as an orebelt for the production management, so a deposit may consist of several orebelts.

The steps of modeling an orebelt are: to unify the logging data → to acquire the orebelt attribute data and generate its identification number (complex geologic body) → to search and acquire the logging and engineering data of the orebodies and horses belonging to the orebelt on the orebelt logging data → to generate the daughter geologic bodies found → to go on searching the daughter geologic bodies until all daughter bodies are done → to generate the orebelt information (identification number, all daughter geologic bodies identification numbers and attributes) .

The other complex geologic bodies modeling is the same as the orebelt' s.

4 GEOMETRIC ANALYSES

On the basis of the geometric modeling of the geologic bodies, we frequently need to do geometric analyses and operations for different applications.

4.1 Geometric operation

Geometric operation means two modeled geologic bodies' set operation which includes union operation, intersection operation and subtraction operation. The geometric operations of geologic bodies are often used to generate new geologic bodies such as orebodies in explosive range, faults cutting rock masses, intersection structures of faults and superimposed mineralization zones.

Two geologic bodies taking part in the operation may be of different types (point-like, linear or planar). When one of two bodies is point-like or linear body, the operation can be done easily by the containment test and the line-area overlapping calculation. When both the geologic bodies are planar, the operation is complex. The opertion of two planar geologic bodies is essentially the geometric operation of their corresponding face blocks A and B. The algorithm of the union, intersection and subtraction operations of the face blocks A and B is as follows.

(1) to build the structure of the daughter arc string of blocks A and B, and define that the walks begin from the same node clockwise along the blocks;

(2) to make the walking direction along block B anticlockwise if the operation is subtraction operation(A-B);

(3) to calculate the all intersection points of the daughter arc segments of blocks A and B, and then to insert the intersection points into the daughter arc segments;

(4) to incorporate or delete the duplicate point if the intersection points are duplicate;

(5) to do the containment test of blocks A and B to calculate the positive-negative value of A and B, and then go to (13);

(6) to take the first intersection point as the beginning intersection point (node);

(7) to link the point to a new block C, set traversing flag on the intersection point of blocks A and B, and then walk along another block if the operation is union (intersection or subtraction) operation and the character value of the intersection point is negative (positive);

(8) to fetch the next node, and go to (10) if it is an intersection point;

(9) to link the node to block C;

(10) to go to (11) if walking to the beginning intersection point, or go to (7);

(11) to incorporate the same adjacent points in block C, judge the positive-negative value of block C, and then build the new block' s model and store it in the face block data table;

(12) go to (6) if there are un-traversed intersection points, or go to (13);

(13) to build the new geologic body(identification number, its face blocks' identification numbers, attributes) and write it in the planar geologic body table.

In carring out the union, intersection and subtraction operations of the face blocks A and B, it is necessary for us to pay great attention to the calculating errors and duplicate points' processes when calculating the intersection points of the daughter arc segments one another[3].

4.2 Entirety property of geologic body

In the application system of the geometric modeling of the geologic bodies, it is necessary to calculate the area, average grade, linear productivity, extension direction, shape center, arc length and others of a geologic body, those properties are called as entirety properties of the geologic body. The entirety properties can be calculated from the geometric and attribute information of geologic bodies. Therfore, if the geometric modeling models of geologic bodies have been built, it is very convenient and flexible to calculate various entirety properties. The calculation of entirety properties is relative to integration operation which can be done by direct method or approximate discrete method.

(1) The area A of a planar geologic body is

$$A = \int_F \int dx\,dy$$

where F is the geometric domain (face block) of the planar geologic body.

(2) The shape center (x_c, y_c) of a planar geologic body is

$$x_c = \int_F\int x\,dx\,dy/A, \quad y_c = \int_F\int y\,dx\,dy/A$$

(3) The average grade C is

$$C = \Sigma l_i c_i / \Sigma l_i$$

(4) The linear productivity is

$$m = A \cdot D \cdot C$$

where D is the average volumetric mass of the geologic body.

5 APPLICATIONS

5.1 Automated ore-delineation

When plotting generalized geologic logging maps (geology-survey maps) and calculating ore reserves, it is necessary to locate and delineate ore bodies and boundaries on industrial indexes, so ore delineation is the premise of correctly plotting maps and calculating reserves. To achieve at the automatic generating and plotting of geology-survey maps, we must first be able to delineate ore bodies automatically. The automatic ore delineation is to acquire limitation points of ore bodies and link the points to form boundaries (limitation lines) and ore bodies directly based on the geologic logging raw data and survey, analytical data. According to this, delineating ore bodies automatically is also the procedure of building the geometric models of planar geologic bodies. The result of the automatic ore delineation should be in accord with or near that of the manual delineation[4].

5.2 Automatic establishment of limitation points of ore bodies

Ore bodies limitation points are the base points for the boundaries or limitation lines of ore body and the points bear geometric information (coordinates) and attribute information (ore body types, ore sizing), which can be expressed by the point-like geologic bodies models. The geometric information (coordinates, etc.) can be got by the projection calculation (drill projecting, trench projecting and so on) of the survey points of prospecting engineering, and the attribute information by dividing ore on industrial indexes based on the logging raw data and continuous sampling analytical data. Actually, the automatic establishment of ore limitation points is equivalent to the ore delineation in a single drill or trench[4].

5.3 Automatic establishment of ore limitation lines

On the base of the models of the limitation points of the ore bodies in separated drills or trenches, we can link the ore limitation points in adjacent drills or trenches along the strike or dip of ore bodies to form a natural limitation line which can be expressed by a linear body model owning geometric, topological and attribute information. The limitation points making up a limitation line should have consistent attributes, so when forming limitation lines by linking limitation points, it is necessary to select consistent limitation points for the construction of the linking point strings in accord with geological conditions. Therefore, the automatic construction of the linking strings of consistent limitation points is the key to the automatic modeling of ore limitation lines and the automatic ore delineation. The construction of linking strings of consistent limitation points may be greatly different because of variation of geological rules of ore bodies. According to this, the link rules must be defined previously. The link rules can be built on the summarization of geological regularities and the experience of manual ore delineation, and then be transformed into the quantitative link rules. The link rules for Panzhihua ore deposits are given as follows.

In Panzhihua iron ore deposits, the ore bodies (strips) stretch along the general trends of the ore belts and keep parallel approximately with the boundaries of the ore belts, so linking the base points of ore boundaries should be paralleled with the limitation lines of the ore belts as best as possible. If regarding an ore belt limitation line as a baseline, the linking line of the base points G_0 and G_1 of an ore body should satisfy the quasi-parallel rule

$$|\alpha| \leqslant \alpha_0$$

where α_0 is quasi-parallel critical angle (e. g.

15°), and $|\alpha|$ is the angle of L and L_0. That is, only when the the rule is satisfied, can the link line L of the base point G_0 and G_1 be made.

6 REALIZATION OF AUTOMATIC GENERATING SYSTEM OF EXPLORATION PROFILE MAPS

Many geology-survey management information systems have been developed, but have not arrived at the automatic ore delineation and the automated generating of geology-survey maps yet. Based on the theory and techniques of the geometric modeling of geologic bodies, through the investigation, analysis and design of the system on the view point of software engineering, the authors have successfully accomplished the study and development of the Automatic Generating and Plotting System of Geology-survey Maps AutoGDPS[2], which have been applied in the mines' management and production.

6.1 Generating geologic bodies of exploration profile maps

6.1.1 Geologic bodies composing an exploration profile map

(1) Point-like geologic bodies include: drill control points, ore belts limitation base points, ore bodies limitation base points, faults base points, sampling points, etc.

(2) Linear geologic bodies include: topographic lines, locus lines of drills, sampling locus lines, boundaries of ore belts, boundaries of ore bodies, extrapolated boundaries, boundaries of graded reserves, faults lines, etc.

(3) Planar geologic bodies include: orebodies, graded ore reserves, extrapolated reserves, etc.

(4) Complex geologic bodies include: ore belts, ore blocks, etc.

6.1.2 The order for generating geologic bodies of exploration profile maps

The generating sequence is: to generate topographic lines →to generate locus lines of drills →to generate sampling locus lines →to generate faults lines →to generate extrapolated boundaries →to generate ore bodies →to generate ore belts →to generate topological relations of geologic bodies →to grade ore reserves →to calculate ore reserves.

6.2 Application in mines

The system AutoGDPS has been in run for the management and production of Zhu Mine, Lan Mine, Design and Research Institute, Production Department and other departments of Panzhihua Steel Corporation. From the raw data of mining prospection and operation, the system can automatically generate and plot various geology-survey maps such as exploration profile maps (Fig. 1) and level profile maps, calculate and report ore reserves, and cut the maps to build sectional drawings for the purpose of the departments management and production.

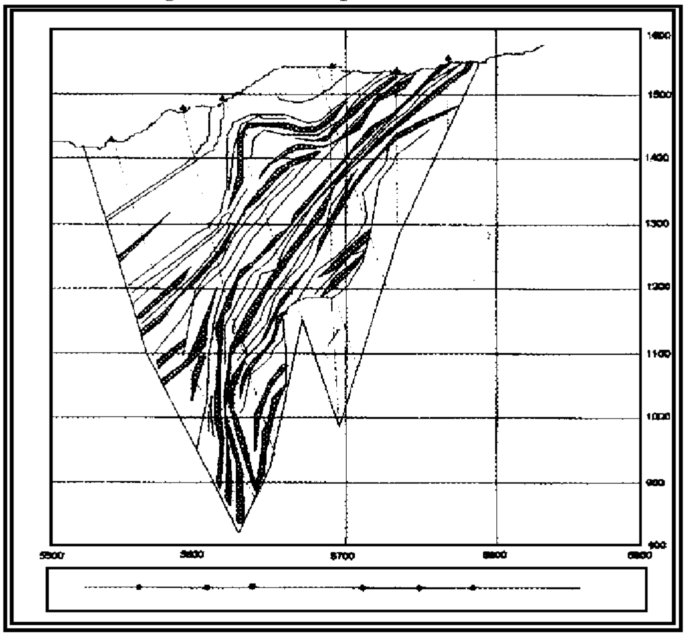

Fig. 1 The exploration profile generated automatically by AutoGDPS

REFERENCES

1 Dai Tagen and Mao Xiancheng. Journal of Central South University of Technology, (in Chinese), 1997, 28(3): 205- 208.

2 Dai Tagen and Mao Xiancheng. Journal of Central South University of Technology, (in Chinese), 1995, 26(5): 565.

3 Victor Milenkovic. Computer-Aided Design, 1993, 25(9): 546.

4 Li Weiming. Calculation Techniques for Geophysical and Geochemical Exploration, 1993, 15(1): 86.

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