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Spatial Analysis and Reasoning for Design Railway Location

Analyse et raisonnement spatial pour les études ferroviaires

Räumliche Analyse und Folgerungen bei Eisenbahnprojektstudien

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SUMMARY

The paper describes a new system for designing railway location applying the theories and technics of information and knowledge processing. It has some object - oriented characteristics which are data abstraction, behaviour sharing, evolution and correctness, wherein the objects are the basic processing units. Every object is divided in two parts: physical and logical. The Materialization Operator and Dematerialization Operator can realize the transformations between the physical objects and logical objects. The concepts and operators used form an algebra system of objects. All of these make the system have the capability of spatial analysis and spatial reasoning. Finally the paper gives the construction graph of the system and an example analysis and its processing.

RÉSUMÉ

Cet article décrit un nouveau système appliquant des théories et des techniques relatives au traitement de l'information ainsi que de la connaissance dans le tracé des voies de chemin de fer. Le système en question comporte des caractéristiques à orientation objet, tels qu'abstraction de données, partage du comportement, évolution et exactitude; chacun des objets, tout comme les unités de traitement de base, sont scindés selon leurs deux parties constituantes physiques et logiques. Un opérateur de matérialisation et un opérateur de dématérialisation accomplissent les transformations entre les objets physiques et les objets logiques. La forme d'un système algébrique d'objets qui en résulte est apte à permettre aussi bien l'analyse spatiale que le raisonnement spatial. Pour terminer, les auteurs exposent la construction graphique du système et le traitement d'un exemple d'analyse.

ZUSAMMENFASSUNG

Der Beitrag beschreibt den Einsatz von Theorien und Techniken der Informations- und Wissensverarbeitung in der Trassierung von Eisenbahnlinien. Im vorgestellten System, das bestimmte objektorientierte Merkmale wie Datenabstraktion, Verhaltensteilung, usw. enthält, sind die Objekte als die zu verarbeitenden Grundbausteine in ihren physischen und logischen Bestandteil aufgetrennt. Die Transformation zwischen dem physischen und dem logischen Objekt wird durch einen Materialisierungs- bzw. einen Dematerialisierungsoperator bewerkstelligt. Es entsteht die Form eines algebraischen Systems von Objekten, das die räumliche Analyse und räumliches Schliessen zulässt. Der Graph des Systemaufbaus und die Verarbeitung eines Beispiels runden den Beitrag ab.

1. INTRODUCTION

The design of railway location is an important part in the whole railway civil engineering. There are many facts to influence it, such as economics, hydrography, geology, geomorphology, topography, and so on. Planning basic railway direction, determining the spatial position of railway and distributing some railway buildings, for example, stations, bridges and channels are its main tasks according to the requirements combining with the natural resource and the economic development of regions through which the railway will pass.

In the past, the design of railway location mainly relied on a lot of data from point to point measured by human beings. Railway engineers repeatedly discussed the merits and demerits among different frames and designed the railway locations according to certain technical standards and some requirements. It was apperently that this design method cost much time and labour and its ability to adapt to new environment was not strong. When a new railway engineering started to be designed, all of designs had to begin from the start again. Much repetition work had to be done to adapt to new requirements and new data, so the design time of the old method was very long and the cost of design was very high.

In the recent years computers have been developed rapidly, especially, the theories and technics of information and knowledge processing have been applied in many areas successfully, so it is necessary and possible to use artificial intelligence in the design of railway location and improve design effectiveness more reasonably.

This paper gives a full discription of a new system for designing railway location. The system combines all sorts of data, information, rules and knowledge applying some theories and technics of information and knowledge processing, processes many complex facts with computers and has the capability of spatial analysis and spatial reasoning substituting engineers. At first, we segment regions according to the pictures taken from airplanes combining with the other data and information and determine rivers, mountains, cities, towns, villages and roads. Every region has many attributes and their values which can represent its typical features, such as mines, oil fields, forests, enterprises, agricutures and populations, etc. All of regions are classified and abstracted to form the basic processing units——objects. Each object includes two parts: physical and logical. The physical objects mainly not only come from the primitive images transformed through the pictures, but also are visualized after processing. The logical objects are logical representation of the objects and are obtained with abstracting operations at diverse levels and take part in all kinds of logical operation and reasoning. Thus the relations among the objects can be formed a net of semantic description, and every object is a node of semantic net. Certainly the semantic net is dynamic changeable at different abstraction levels, so the objects and their properties and attribute values can be queried and indexed. The attributes at higher level are the abstraction of data and information of the objects at lower level, and the objects at lower level can inherit the useful data and information of the objects at higher level.

In the system, there are two kinds of design strategies of railway location. One is from bottom to top, which firstly begins at the start point and the terminal point and goes into deeper levels step by step. The other is from top to bottom, which starts at two basic object nodes and extends outer levels and ends at the start point and the terminal point. Of course the distinction between two strategies is not extrict.

In a word, the system for designing railway location can combine with some theories and technics of information and knowledge processing and improve intelligent level of railway civil engineering. During designing this system, some new concepts, such as pure object and algebra system of object are put forward so that the complete design theory can be formed.

2. SOME BASIC CONCEPTS

In the introduction, we know that the system for designing railway location is based on objects. All sorts of computation and reasoning in the system are carried out through the attributes of objects. As follow some basic concepts are defined.

2.1 Objects

An object is an encapsulation of a set of operations or methods which can be invoked externally and of a state which remembers the effect of the methods.

The system for designing railway location supporting objects is characterised by the following features:

1.modularisation——all details of an object are brought together in one place.

2.information hiding——access to an object is controlled through a well–defined interface; all other details of the objects are hidden from the user of that object.

3.behavioural——the behaviour of an object is captured by the full operational interface presented by that object.

4.object interaction——a mechanism is provided to allow an object to invoke methods on another object.

5.self reference——local operations are accessed in the same way as remote operations by invoking a method on self.

2.2 Physical Objects

Physical objects are real physical meaning of objects. They not only refer to the primitive images transformed through the pictures taken, but also can be synthesized and visualized if necessary. The three dimensional objects such as geography and geomorphology can be shown on sreens of computers.

2.3 Logical objects

Logical objects are abstraction forms of objects and semantic descriptions of physical objects. They represent the logical relations of objects and show the properties and attribute values of physical objects. The attribute values take part in all kinds of computation and analysis in the system.

2.4 Classes

After the concepts of objects, physical objects and logical objects have been defined, they should be classified based on certain rules. A class is a template from which objects may be created. It contains a definition of the state desciptors and methods for the object. The class template therefore provides a complete description of a class in terms of its external interface and internal algorithems and data structures.

2.5 Inheritance

The classifications of objects are made at different levels. The new class is said to be a subclass of the old class. Similarly, the old class is the super class of the new class. The new class therefore shares the behaviour of the old class but has modified or additional behaviour. This sharing of behaviour is the essential feature of inheritance. Inheritance is the incorporation of the behaviour of one class into another. A class which inherits from another class inherits all the methods and attributes of that class.

3.THE ALGEBRA SYSTEM OF OBJECTS

In the system for designing railway location, the concepts, the transformations between physical objects and logical objects and a series of operations on objects can be formed an algebra system of objects which has the capability of spatial analysis and spatial reasoning. Its representation formalized is:

$G\ (V_L, V_P, S, X_0, R)$

wherein:

V_L is the set of logical objects.

V_P is the set of physical objects.

S is the limited non–null set of object names.

X_0 is an element of S and represents the set of object names which is head.

R is the mapping from S to $2^{V_L \cup S} \times V_P$ and is the object rules transformed from all kinds of technical standards of railway location design.

Two–element representation of objects is (A_m, A_i) , whereinA_m is logical objects andA_i is physical objects. Every operator of the system is divided two parts also. OP_m is logical operator and OP_i is physical operator, so the operator can be written as:

$$OP = (OP_m, OP_i)$$

When an operator acts on two objects $X\ (X_m, X_i)$ and $Y\ (Y_m, Y_i)$, it is written as:

$$OP\ (X,Y) = (OP_m\ (X,Y)\ , OP_i\ (X,Y)\ )$$

If OP_m is independent of X_i and Y_i and OP_i is independent of X_m and Y_m, then

$$OP\ (X,Y) = (OP_m\ (X_m, Y_m)\ , OP_i\ (X_i, Y_i)\ )$$

Among the operators MOP(Materialization Operators) and DMOP(Dematerialization Operator) are extremely important, because they can realige the transformations between logical objects A_m and physical objects A_i. If there is an object $X = (X_m, X_i)$ in which logical part X_m and physical part X_i are fully transformed each other, i.e. $\{X_m\} = DMOP\ \{X_i\}$ and $\{X_i\} = MOP\ \{X_m\}$, this object is called the pure object being useful in the system.

Besides above two kinds of basic operators MOPand DMOP, following other operators are necessary to be introduced.

3.1 Combining Operator COM

$$\text{COM}\ ((A_m,A_i),(B_m,B_i))$$
$$=(\text{CONCEPT}-\text{MERGE}\ (A_m,B_m)$$
$$,\text{SUPERPOSE}\ (A_i,B_i))$$

Explanation: physical objects A_i and B_i add to form a new physical object whose corresponding logical meaning combines two concepts of logical objects A_m and B_m, for example, COM (City A, Station B) = (Station B in City A)

3.2 Subtracting Operator SUB

$$\text{SUB}\ ((A_m,A_i),(B_m,B_i))$$
$$=(\text{CONCEPT}-\text{DIEF}\ (A_m,B_m),\text{REMOVE}\ (A_i,B_i))$$

Explanation: when physical object B_i is removed from A_i, the logical meaning of A_m will change and form a new concept, for example, SUB (Town A having bridge B, Bridge B) = (Town A without bridge B)

3.3 Inverting Operator INV

$$\text{INV}\ (A_m,A_i)$$
$$=(\text{CONCEPT}-\text{INV}\ (A_m),\text{INVERT}\ (A_i))$$

Explanation: this operator is used to transform objects which are under ground and above surface.

3.4 Marking Operator MAR

$$\text{MAR}\ ((A_m,A_i),(B_m,B_i))$$
$$=(\text{CONCEPT}-\text{MARKING}\ (A_m,B_m),\text{MARK}\ (A_i,B_i))$$

Explanation: marking refers to the important feature of objects. Object B is a feature of object A, for example,B represents mountains, A is a city, MAR (A,B) = (City A with mountains)

3.5 Enhancing ENH

$$\text{ENH}\ ((A_m,A_i),(B_m,B_i))$$
$$=(\text{CONCEPT}-\text{ENH}\ (A_m,B_m),A_i)$$

Explanation: this operator add some attributes of object B to object A, so the meaning of A will expand.

3.6 Indexing Operator IDX

$$\text{IDX }(A_m, A_i) = (\text{CONCEPT-REDUCE }(A_m)\ ,\ \text{IMAGE-REDUCE }(A_i))$$

Explanation: the meanings and images of objects acted by IDXare reduced so that the simple features of objects are represented.

3.7 Clustering Operator CLU

$$\text{CLU }((c_1,e),\ldots,(c_m,e),(\{\},p_1),\ldots,(\{\},p_n)) = \{(c_i,p_j):1 \leqslant i \leqslant m, 1 \leqslant j \leqslant n\}$$

Explanation: (c_i,e) represents physical object without any concept, and $(\{\ \},p_j)$ represents logical object which has pure meaning or concept. Clustering Operator makes physical objects have adequate logical meaning and concept.

3.8 Similar Operator SIM

$$\text{SIM }(X,Y) = (\text{SIM}_m\ (X_m,Y_m)\ ,\text{SIM}_i\ (X_i,Y_i)\ )$$

Explanation: this operator can compare the similarity between two objects X and Y which include the similarity between two physical objects X_i and Y_i and the similarity between two logical objectsX_m and Y_m.

3.9 Existing Operator EXI

$$\text{EXI }(X,Y) = (\text{EXI}_m\ (X_m,Y_m)\ ,\text{EXI}_i\ (X_i,Y_i)\ )$$

Explanation: this operator can tell us if there exists X in Y.

4. THE SYSTEM CONSTRUCTION

The old design method of railway location required that the engineers be imaginative and familiar with all sorts of technical standard. Now computers can substitute the engineers to design railway location based on above concepts and operators. When the decision to build a railway between city A and B has been made, first of all, the pictures of geography and geomorphology taken from airplanes are inputed into computer with an image scanner. The equal height map of the entensive area between A and B is established combining with other measure data, as shown in Fig 1.

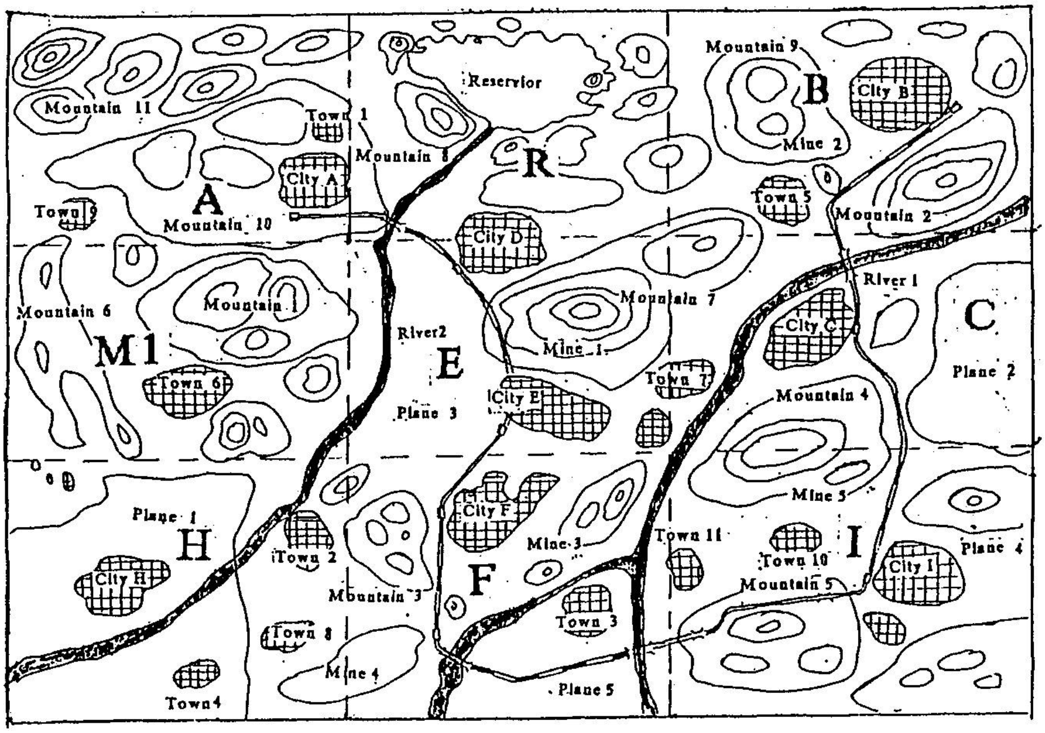

Fig.1 The map of an example processing.

Besides cities A and B, there are other seven cities (C, D, E, F, G, H, I), eleven towns, five planes, eleven mountains, two rivers and reservoir N, etc. According to typical features of regions, the area shown in Fig.1 is classified and segmented to form several regions. Each region is nominated with the most typical charateristics, and other features, such as geology coordinates, areas, natural resources, population, geology constructions and the product values of industry and agriculture, and so on, are its attributes. Thus we can use one point to represent one region segmented. The relations of points and regions are one–to–one mapping. The points are the corresponding abstraction form of the regions. If we think the regions as physical objects, the points are logical objects and the relations of the points represent the semantic descriptions of the regions. Following an example is given.

Region F is nominated as the name of city F after segmented, because city F is the important feature of region F. In the region F there are two mines (Mine 3 and Mine 4) , Mountain 3 , Plane 5 and River 2. They are the attributes of point F, shown in Fig. 3 and Fig.4.

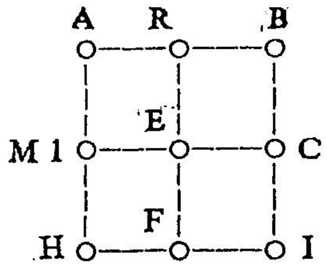

Fig.2 Semantic description net of Fig.1.

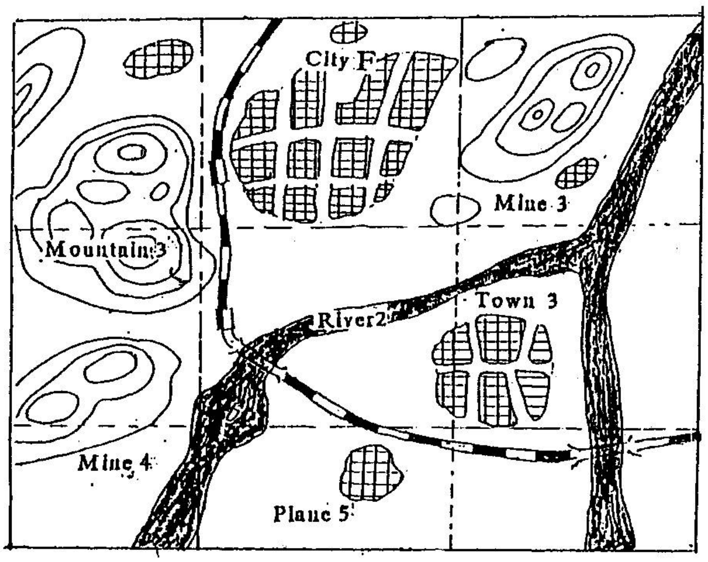

Fig.3 The detailed map of region F in Fig.1 at deeper level.

Region F

Name: F

Attributes:

Average Latitude: 40

Average Longitude:95

Average Height:400

(above see level)

Area:100 sq.km

Population:100,000

Mines: a coal and an iron

Industry: a steel factory

Mountain: a forest

Fig.4 The attributes representations of region F.

At certain abstraction level, the points form a semantic net in which every point is a node. The net can change dynamically based on the different levels. The attributes of subclasses at deeper level inherit the ones of superclasses at the fore level automatically and augment some if neccessary at the same time. The semantic nets take part in spatial analysis and sapatial reasoning and caluculate the meaning value to build a railway at one node and determine technical difficulty of building and engineering cost.

Fig.5 shows the construction of the system for designing railway location. The system consists of a large system knowledge–base which collects all kinds of information, such as geometry, graphy, hydrography and economy. Every kind of information has relative independence and completeness. In the system there are the capabilities of index and query. Under certain environment, we obtain information stored in the system knowledge–base, space constructions and logical relations and semantic descriptions of objects. The system realizes on SUN / 386 in C language. SUN CGI graphic interface system makes the system knowledge–base have the graphic information base.

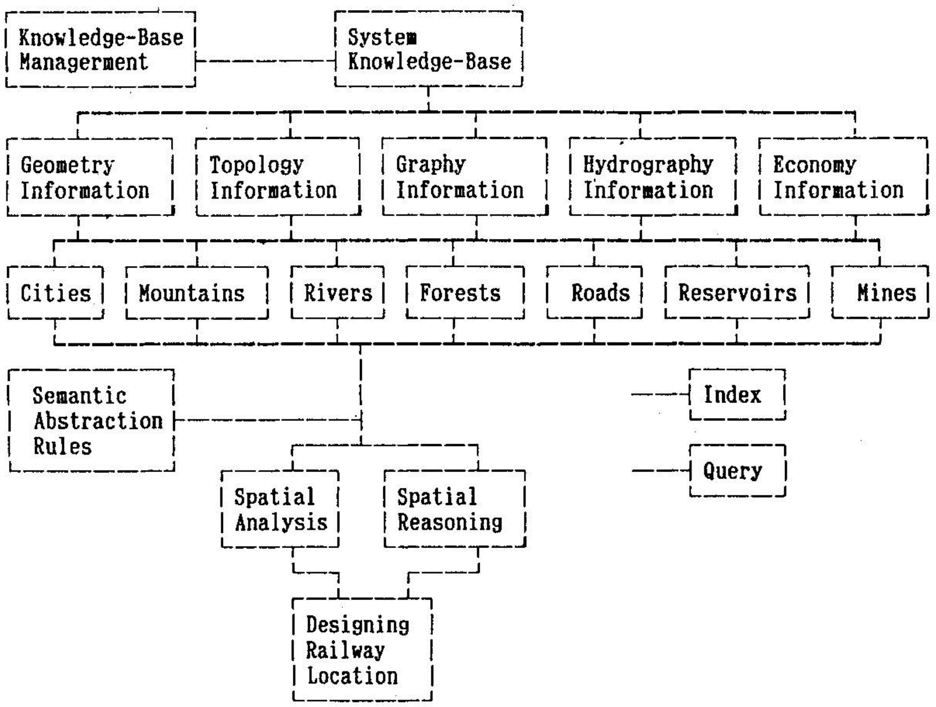

Fig.5 The construction graphy of the system.

5. CONCLUSION

We have described a new system for designing railway location. The system has some object–oriented characteristics which data abstrction, behaviour sharing, evolution and correctness. The semantic nets whose nodes represent objects are the system framework. The techniques introduced in the system are encapsulation, classification, flexible sharing and interpretation. The new system improves the old methods whose measuring, charting and reasoning mainly rely on human beings and decreases designing cost and labour power greatly. The theory and method of the system can be applied to other engineerings.

REFERENCES

1. CHANG S.K., Principles of Pictorial Information Systems Design, Prentice–Hall, Inc.,1989.
2. BLAIR G., GALLAGHER J., HUTCHISON D. and SHEPHERD D., Object–Oriented Languages, Systems and Applications, Longman Group UK limited, 1991.
3. MULLIN M., Object Oriented Program Design, Addison–Wesley Publishing Company, Inc., 1989.
4. CHANG S. K., Visual Reasoning for Information Retrieval from Very Large Database, Journal of Visual Languages and Computing, pp41–58, Vol.1, No.1, March 1990.
5. GOUTAS S., SOUPOS P., CHRISTODOULAKIS D., New Approach Towards an Object–Oriented Database System, Microprocessing and Microprogramming, Vol.27,No.1–5 August 1989.