DESIGN OF GEO-ONTOLOGY BASED ON CONCEPT LATTICE

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ABSTRACT:

Ontology is an explicit specification of a conceptualization in Artificial Intelligence. Geo-ontology is a very complex and intricate concept. Lots of researchers begin to research Geo-ontology, but many of them just transplant ontology concept of information science into GIS. Based on existed expert's knowledge, starting from the basic components, we determine the scope of Geo-ontology at first. And then analysing the ontology property of each geographical concept, we use concept lattice to build the relationship among geographical concepts after confirming the scope of Geo-ontology. Completing the collection of concepts' meaning, attribute, picture and instance, we design a prototype system of Geo-ontology using VC6++ and SQL Server at last.

1. INTRODUCTION

Ontology is a discipline of Philosophy, which deals with what it is, its essence and law in western philosophy. While in ancient Chinese philosophy, it's the theory that explores the inherent reason and evidence of birth, existence and development with regard to everything on the earth. During the last few years, the research, development and application of ontology have gradually involved in many subjects, such as computer, artificial intelligence and biology and it has achieved some achievement. As a philosophical concept, ontology has the most ambiguous meanings, which was first introduced into information science, then into the field of GIS. We construct the ontology by abstracting/generalizing an application field into a series of conceptions and relations of these conceptions, and that makes it convenient for computer to process the information. Now, ontology has been becoming the core problem concerned by many research fields such as knowledge access and presentation, integration of database frame and process of natural language.

As an efficient tool to manage spatial data, Geographical Information System has become the main platform for managing and processing spatial information. From geographical entity to geographical data, geographical data to geographical information, and then to geographical knowledge, it reflects a quantum jump on cognition of substance, energy and information by human. At the same time, it brings a great challenge to the research of GIS theory and methods, so we should integrate different kinds of geographical information to satisfy the different application. The geographical data, geographical information and geographical knowledge have been widely used in many industries at present. But most are based on the understanding of main body, and this caused the problem "might share but can not use" (Jianjun Chen, 2006).
Research the problem about Geo-ontology is the GIS development trend (Min Sun, 2004). In the domain of geographical information science, Fonseca (2002), Frank (2001), Smith (2001), Agarwal (2005), Kavouras (2005), Lutz (2006, 2007), Klien (2006), Agustina (2007) have done lots of work about Geo-ontology and its application, and gained some corresponding achievements.

Geo-ontology is a very complex and intricate concept. When many experts begin to research Geo-ontology, they just transplant ontology concept of information science into GIS, seldom consider the particularity of geographic information itself. In this article, firstly the scope of Geo-ontology is explained. Then the design of Geo-ontology prototype system is illustrated in detail. Lastly, we give the system's prototype interface.

2. DESIGN OF GEO-ONTOLOGY

2.1 Basic Components

At present, the definition of ontology has been unified in computer science, while how to describe the ontology has not a uniform criterion. There exit the methods such as triple (Zhi Jin, 2000), four elements (Tomai, 2004, Wei Cui, 2004) Five-Tuple Array (Perez, 1999) and six elements etc. The representation of four elements and the six elements was accepted by the researchers of ontology among these methods.
Geo-ontology is a description about geographical information. Zhi jin(2000), Wei Cui (2005), Yang An(2004), Mao-jun Huang(2005) have made a large number of research from different aspects and discussed on its composition. Combined geographical information's characteristic with domain expert's knowledge, based on these research results, we defined Geo-ontology as follows:

$$\text{Geo-ontology} = \{C, R, A, X, I\}$$

Where C (concepts) represents the concept set of geographic object; R (relation) is a relation set and it mainly describes the

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relation set among concepts; A (attribute) shows attribute's set of geographic objects; X (axioms) is a lot of axioms and it is a constraint rules among the concepts, relation and attributes; I (instances) in a material object and I is a set of definition about instance.

In this article, we define each concept's ontology property through its conceptualization on the basis of the method of formal ontology, build the concepts' ontology property set of fundamental geographical information, confirm the semantic relation among fundamental geographical information, and realize the semantic representation based on formal ontology through lattice concept.

2.2 Scope of Geo-ontology

The scope of Geo-ontology is different according to different application. In this article, we define scope of Geo-ontology as concepts which belong to the national fundamental geographic information.

At the outset, the data of original experiment all came from the specification for feature classification and codes of fundamental geographical information and cartographic symbols for national fundamental scale maps. But according the further research, we find these concepts can not meet demand of other relative department. The most problem is that lot of concepts are in deficiency in many domains. At last, we modify the scope of Geo-ontology according the concepts of land resources information, the dictionary of geography and Cihai besides the specification for feature classification and codes of fundamental geographical information and cartographic symbols of national fundamental scale maps.

2.3 Methods of Building Geo-ontology

Different people gave different methods about the building of Geo-ontology. These methods are common with methods of other ontology. At present, there is not a standard method for building Geo-ontology. But there exists a lot of domain's knowledge such as cartographic symbols for national fundamental scale maps, specifications for feature classification and codes of fundamental geographic information. This knowledge has an important role in the building of Geo-ontology. Based on this knowledge, we decide the main process of building Geo-ontology as follows:

1. Confirm the scope of Geo-ontology
2. List the ontology property of geographical concept
3. Ensure the relationship among geographical concepts.
4. Collection of Concepts' meaning, attributes, picture, and instance.
5. Prototype system of Geo-ontology

3. REALIZATION OF GEO-ONTOLOGY

Giver the scope of Geo-ontology, the ontology property and the relationship become the primary factor in building Geo-ontology.

3.1 Ontology Property of Geographical Concepts

Geographic object include information about geographic concept types, characteristics, relations, etc. Concept types can be defined as abstract specifications of entities that exist or may exist in some domains. Properties are the attribute, features, or characteristics of entities. Properties distinguish the concept types, which they characterize (Kokla, 2001). Properties play an important role in explaining our ability to recognize and categorize things in the world around us (Stanford Encyclopaedia of Philosophy).

Aristotle thinks that property can not independently exist without ontology (Zi-song Wang, 1997). He clearly stated that any individual has the process of production and perish. Even if it exists, its properties changes continually but this change is a relative concept. He pointed out that the change is not the ontology (distinguishing from epistemology) itself but is its property. The thing's property includes internal property and external property. Internal property belongs to object itself and it is the natural property, it is not alterative with people's will. But the external property (such as name, length) has sociality, different object has different representation. It is obvious that internal property is prior to external property.

There are lots of properties describing geographic concept, but not all properties can become ontology property. For example, the property of "river" could be fractionized into length, the capability, the velocity of water and so on. Whereas these properties are not the essence properties of the river, for the ontology property is the property which describes the river's essence.

Based on existing national fundamental geographical information concept, the article summarized the ontology property of all geographical concepts according to the process of production, development, perdition of geographic object. All ontology property comes from the semantic meaning of all geographical information concepts. The ontology properties of concepts include the spatial, time, component, and function etc. These ontology properties are formed the ontology property set which established its own system through the defined concept of meta-concept and multi-concept.

For example, according to the process of production, development, perdition of hydrological feature, we conclude its essence property as follows: matter, function, spatial shape, time, size, state and so on. These properties are not the ontology property of all concepts. Some property is ontology property of one concept, but it is not ontology property of another concept. We acquire these ontology properties through some rule that we make.

3.2 Semantic Relation among Geographical Concepts

Using the theory of Mereology which belongs to taxonomy as the basis of concepts semantic relation, based on the established ontology property of geographical concept, we realize the calculus among geographical concept's semantic and automatically build semantic relations' system among geographic information concepts with the aid of concept lattice. Concept lattice is the central notion of Formal Concept Analysis (Wille 1992, Ganter and Wille, 1999). Formal Concept Analysis (FCA) is a theory of concept formation and conceptual classification. Several researchers have further elaborated FCA in different domains (e.g., Spangenberg, 1999; Granter, 1989; Kent, 1995; Faid, 1997; Deogun, 1998; Priss, 1999).Yun-yan Du (2005) and Kavouras (2002) have used it in geographic domains.

Concept lattice is defined as subsets of objects and attributes. These concepts and their relationships between them form a lattice in which the meet and join of any combination of elements are given by definition. Thus, a concept lattice not only contains concepts corresponding to each object, but also concepts corresponding to the meet and join of other concepts. We can realize the semantic relation of fundamental geographic information through the ontology property that we conclude by concept lattice.

Gangemi(2001) thought that people must first understand all kinds of relation (such as is-s, part-of). He introduced some basic relationship, for example, instantiation, and membership, parthood, connection, Location, extension and dependence relation. At the same time, he gave some intuitionistic property about these relationships. Diverse relation play an important role in different ontology, so combing diverse relation helps us understand the difference of ontology which builds in different relationship.

Combining the characteristics of geographical information concepts, we discuss the various relations from several aspects, such as classification relation, concept-semantics relation, concept-attribute relation and spatial relation in Geo-ontology.

3.2.1 Classification relation: According to the different levels, classification relation mainly includes synonymy relation and hyponymy relation.

Synonymy relation mainly represents that A is identical to B from the definition. For example, the concept of waterfall and drop express the same thing in geographic concept database, so we think they are identical.

Hyponymy relation describes the classification relation among different concepts which they have common property. It reflects the relation of concrete and abstract, individual and collective of concepts. There are two methods to express the Hyponymy relation in Geo-ontology:

(1) Is-a
This relation points out that there is a hyponymy relation between one concrete thing and one abstract thing, its definition is “is-a”, representing one thing is a specific example of another thing. Fox example, the han-jiang river is a continuous river; it can be expressed as “Han-jiang is a continuous river”. It can be expressed as is-a(x,y), The semantic-interpretation is that X is a special case of Y.

(2) Kind-of
This relation mainly expresses the inheritance relationship among concepts. The intuitionistic definition is “kind of”. It represents that one thing is a kind of another thing, which is similar to the relationship between the class and the subclass. It expresses as kind-of(x,y), the semantic-interpretation is that X is kind of Y.

3.2.2 Concept-semantics relation: Two concepts in the classification relation lie in different logic levels, concept-semantics relation will discuss on the relation from concepts’ structure. Concept-relation mainly includes part-whole relation, dependency relation, instantiation relation and member relation.

(1) part-whole relation
Part-whole relation mainly discusses the relationship among concepts according to the concepts structure. In the building of Geo-ontology, part-whole relation is mainly described as the relation of Component/Integral-object and Place/Area. The former is as in ‘the waterfall is part of a river’; the latter is as in ‘some city is part of some province’.

(2) Dependency relation
In Geo-ontology, Dependency relation is defined by the two following situations: one is the relation that the part depends on the whole as we build the part-whole relation, the other is that there is no relation between two concepts but one depends on another, for example, the relation between the dam and the reservoir, the entrances and exits of underground rivers, the railway station and railway.
We use D(x,y) to express “x depend on y”, described as “x dependency-on y”.

(3) Instantiation relation
The instantiation relation is the relation between the concept and the entity in nature. In general, there is no corresponding entity to the abstract geographical information concept while the material geographical information concepts have lots of instances.

(4) Member relation
Member relation is the relation between the gather of the concepts’ extension and internal elements of concepts. Member relation differs from instantiation relation; it is a relation that defined in two different logic levels.

3.2.3 Concept-attribute relation: Besides the above relationship among concepts, there is a concept-attribute relation between the “concept” and “the concept representing the attribute of concept”. This relation mainly expresses that one concept is another concept’s attribute. For example, the price is one of attributes of a desk. The concept-attribute relation is various, different geographic information entities have different attribute, so concept-attribute relation is unfixed, and it is related with the concept and its attribute. For instance, the relationship between the river’s name and itself is “Name-of” relation.
Figure 1 is part of relations which we discuss.

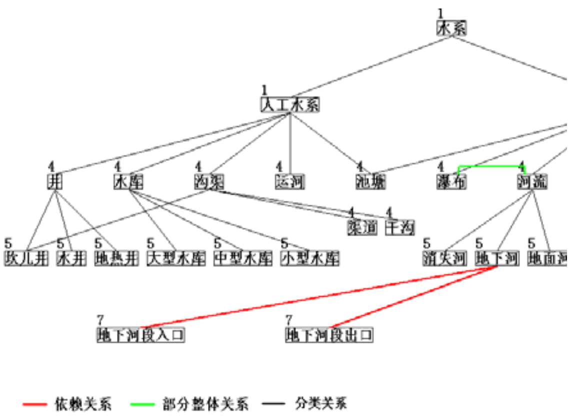

Figure 1. Semantic relation among geographical concepts

3.3 Collection of Concepts’ Meaning, Attributes, Picture, and Instance

In Geo-ontology, the main concept meaning of fundamental geographical information mainly derived from the existing cartographic symbols, specifications for data classification and codes of fundamental geographic information and other relevant industries' classification and codes etc. We update the meaning according to the geographic character.

Attributes are important in geographical representation. In Geo-ontology, we try our best to represent all attribute which belong to each concept. Because the attribute of each concept which has different slot such as type, range of value and other character, we need to compute by hand.

At present, the picture of each concept mainly comes from the source of internet. We modify these pictures by the software of photoshop. We acquire some special pictures using the camera of ours.

All instances come chiefly from the relevant expert knowledge and statistic data.

3.4 Prototype system of Geo-ontology

Turning to Visual C++ and SQL database, we can realize the Geo-ontology according to the upper result. The process is as follows:

3.4.1 Organization of origin data: It mainly includes the collection and store of resources such as definition, picture and attribute of each concept. Using access database, we build several data table to store the origin data. These tables can be classified by two kinds. One is the concepts of fundamental geographic information which include road, building, geomorphy, etc. The other is the accessorial information which contains the codes of river, lake, reservoir, the serial number of road etc.

3.4.2 Design of database in SQL Server: In SQL Server, we defined twenty-seven data table which store the results of classification. The name of the key concept table is NR which includes the concept name, all kinds' relation and other concepts (Figure 2). Nr table mainly store the context of classification through concept lattice. Table 1 is the part of the definition of each field..

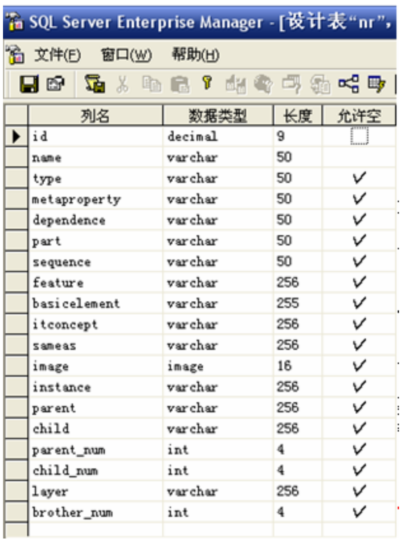

Figure 2. Data structure of Nr Table

Serial number	name	definition
1	id	The id of each record
2	name	Name of Geographic object
3	type	Type of geographic object
4	relation	Relations of geographic object
5	feature	Attribute of geographic object
6	Ontology-property	Essence property of geographic object
…	…	…

Table 1. Definition of Each Field in Nr Table

The index information of concepts is very important in this step. All index come from the index table. We set up a set of index tables from A to Z. In these tables, the data is organized by pingyin of Chinese character and its name and id is similar to the NR table.

3.4.3 Realization of Geo-ontology

from the ontology property of national fundamental geographical information, according to the characteristics of geographical information, the article identifies all composition of elements, designs the prototype system of national fundamental geographical information Ontology.

According to the methods of building Geo-ontology, we design the interface of system as shown in Figrue 3. In the prototype system, we can realize the index of concept and confirm the place of each concept. At the same time, we can import or delete data. Through this system, geographical concepts and its relationship was expressed clearly.

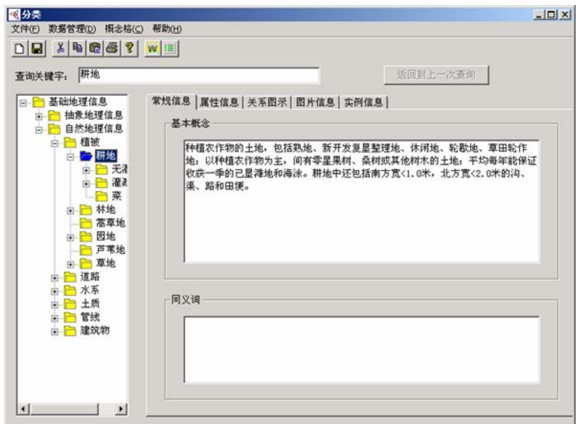

Figure 3. Interface of Geo-ontology

4. CONCLUSIONS

Starting from the ontology property of geographic concept, using concept lattice, we express the relationship among concepts. And then using Visual C++ 6 and SQL Server2000 database, this article realizes the prototype system of Geo-ontology. In this article, we give the process in detail. But the geographical object is very complicated. Moreover, the Chinese character is more complicated than other characters. There is still much work to do in building of Geo-ontology.

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