KNOWLEDGE REPRESENTATION OF CARTOGRAPHIC GENERALIZATION

YING Shen [a], LI Lin [a]

[a] School of Resource and Environment Science, Wuhan University,129 Luoyu Road, 430079,Wuhan, P.R. China
senying@sina.com

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ABSTRACT:

Data, information and knowledge are the three inseparable levels in info-flow. Data are a serial of descriptions of discrete facts and geospace from the ontological view, which are considered as records in database. Information that conducts user's viewpoint to specific matter is a collection of facts or data. While knowledge exist in our brains which are the fusion of experience, information and apprehension. We consider that knowledge is the highest description of geospatial phenomena, processes and concepts, and we use it to interpret, predict and communicate.
Knowledge representation is an important branch of computer automation, which is the foundation of knowledge reasoning and AI. Map generalization is a decision process with many artificial intervenes. How to represent spatial knowledge and how to convert the export's knowledge and experience in brain to formal knowledge is a key of the implementation of automated map generalization, and it is still a long run.
Knowledge about map generalization is experience and summarization about the abstraction, generalization and characterization of spatial information. The paper presents the approaches of knowledge representation of map generalization and the principles for expert system, then analysis the type of map generalization knowledge and divide it into three classes: description knowledge and facts, reasoning and process knowledge, evaluation knowledge. The paper illustrates representation of knowledge about map generalization based on rules and models. Rule representation uses the selection and action operations to simulate the process of cartographer's manipulations with some geometric and semantic constraints. Model representation deals with map through the essential information transmission about map models, and is divided into deep model generalization (map model) and shallow model generalization (symbol representation). Finally the paper develops the organization of knowledge and expert system in map generalization in details.

1. INTRODUCTION

Recently, knowledge representation is a new field with the development of computer science. It is the foundation of intelligence expert system because the ability of intelligent system's solution at a large degree depends on the quantities and qualities of the knowledge it owns. In information science, knowledge, data and information are inseparable. Fischler (1987) says: knowledge is the storage model that people use to interpret, forecast, and response to the outside world. We think knowledge is the abstract descriptions of reality, phenomena and conception at the highest level, which people use to explain, reason and communicate, and it's the result of the analysis, generalization and abstraction of information. Geographical knowledge refers to the knowledge of temporal and spatial data based on geographical spatial objects, which is the fundament of spatial reasoning and spatial decision. Knowledge of cartographical generalization is the knowledge and experience of information abstraction, summarization, generalization in geographical space, and it's the source of automatic map generalization.

Map generalization is a complex decision process with highly artificial interference. How to describe and represent the geographical information properly and how to convert the experts' knowledge and experience to the knowledge that computers can handle automatically are the keys of intelligent cartographic generalization, and also the long term problem of GIS studying. Cartographical generalization system not only deals with plenty of spatio-temporal data, but the more important, it needs the abundance of knowledge and experience of cartographic experts, which is the difference of map generalization system from other GIS software. The key of a cartographic generalization system is the quality and quantity of the knowledge of cartographic experts, depending on the formalization representation of map generalization knowledge and relevant organization in accordance with the cartographic rules.

2. KNOWLEDGE ANALYSIS OF CARTOGRAPHIC GENERALIZATION

Cartographic generalization is an important field of cartography, the content of which is to extract and generalize the elements about geographical phenomena and objects in accordance with the cartography principles and expert knowledge to get representation at different scales. Map generalization knowledge is primarily consist of cartographic task, feature analysis, graphical symbol appointment, demarcation standard definition, generalization operation, etc, which chiefly comes from three aspects (Qi,1998):1)from current criterions and specifications. It includes data interchange standard in geographic/cartographic database and cartographic generalization standards and detailed regulations in edition synopsis of general map; 2) conclusion from the experts' experience of cartographic generalization; 3) extracted rules from database map analysis. Barbara (1991) discussed the relevant knowledge and rules of map generalization. To analyze the knowledge of map generalization is to discuss the characteristics of map generalization knowledge from different aspects, reveal inherent relationships among map generalization knowledge, choose proper method of knowledge representation.

2.1 Fact and Descriptive Knowledge

Descriptive knowledge represents the static knowledge of request and use of map generalization, the relationship and attribute of spatial data. For example, the scale before and after generalization is 1:10000 and 1:50000, generalization objects are general geographic features. Descriptive knowledge mostly refers to fundamental fact, and can be set up before generalization reasoning and decision. Sometimes descriptive knowledge is a logical result speculated from common facts. They offer qualifications about cartographic generalization.

2.2 Deduced and Process Knowledge

Deduced Knowledge and Process Knowledge are based on factual knowledge to reason and decide, which primarily comprises generalization analysis and implementation of generalization task (Wang,2001). Generalization analysis knowledge includes analysis and determination of features characteristics, distributed density, distributed character and spatial pattern, spatial relationship (topological relationship), semantics influence. Implementation knowledge includes various transformation (such as simplification, aggregation) of graphs, selection of generalization operator, sequence of generalization operation, and so on. Qi and Pan (1998) use such knowledge to define structural recognition, process recognition, process modeling, generalized quality and to define next behavior and operator. Deduced knowledge is computer formal representation of the experts experience and knowledge of map generalization, usually expressed in the form of "IF…THEN" sentence. For example, if the area of polygon less than 0.5 square centimeter, then delete this polygon. Process knowledge refers to the model representation of cartographic generalization (see section 4)

2.3 Generalization Assess Knowledge

Assess knowledge is used to not only judge the generalization rules, but also assess the generalization quality, such as square root law.

These three aspects knowledge are not isolated, but are supplement and interactive in practice. For example, when we use deduced knowledge to reason in map generalization, it will trigger process knowledge. Also the application of process knowledge needs the parameters about descriptive knowledge.
Knowledge representation is an important section of information system design and operation. It symbolizes and formalizes the knowledge of experts field and translates them into the form which computer can recognize and process. But with the limitation of computer language, we often use the formal knowledge representation to realize the automatic process. Most knowledge representations are based on logic, relationship, object, regulation, semantic network, model and ontology (Kong,2001). For cartographic generalization system, the difficulty in knowledge representation is how to express the knowledge of cartographic experts with systematic and integrated method, and eventually to solve real problems. As to cartographic generalization knowledge, the article will pay more attention on knowledge representation based on rules and models.

3. KNOWLEDGE REPRESENTATION OF CARTOGRAPHIC GENERALIZATION BASED ON RULES

During knowledge representation based on rules, various alternations are set to trigger and processes. System based on rules can be achieved by several methods: fact description, pattern matching, logic deduce. We also use BNF to represent productive knowledge: IF<factor>THEN<conclusion>.

Generalization knowledge of both traditional map and electronic map can be composed of two components: knowledge that has already come truth and the experience of cartographer and the knowledge of experts. Fact knowledge means descriptions and rules related to cartographic generalization, most of which are transformation, quantification and realization of experts' knowledge. In this paper we mostly use regular representation of generalization knowledge by the geometric threshold of cartographic generalization and generalization decision to represent.

Confined by the condition of eyesight or material, mapmaking and print, the capacity of paper plane map or electronic map is limited, which influence the selection and expression of map information in map generalization. A main criteria is map symbols with the minimum size of geometric shape and symbols, including points, lines, geometric shape, outline, curve, and etc (Barbara,1991; Wang,2001). We can describe the productive rule as:

- IF{the object is a lake & its area is bigger than 1 cm^2},THEN{select the lake}; ELSE{delete it}.
- IF{the object is a river & its length is shorter than 10 cm^2 & the distance from other rivers are longer than 2 cm^2},THEN{select it}.

Schema language of cartographic generalization is developing. It enables the developers to define and describe the rules of cartographic generalization. Generalization is to define how source scale data is selected and then transformed to object scale database. Generalization rules are divided into two parts: "selection" rules and "action" rules. Selection depends on the types, attributes, and spatial relationship of map objects. After selection, build corresponding objects in object database with "action" rules. During combing buildings, the first thing to do is to build an aggregation of buildings that are combined and characterize the rectangle. The "selection" rules are described as:

```
Rule1: "Building selection"
Source: Building
Target: GBuilding
Define BSet() as
        Select * from Building b
        For each b in BSet()
        If( b.Area>10)
        Then Create GBuilding
            Shape:=b.Rectanglated()
```

Then we need to aggregate the selected buildings with the following rules:

```
Rule2: "Building Aggregation"
Source: Building
Target: GBuilding
Define Mergence() as
  Select b1 and b2 from Building b
  If(b1.Distance(b2)<2&& not Rule1)
  Then Create GBuilding
```

Shape:=Convex(b1,b2)

Schema language of generalization rules has certain constraint and sequence, and generally we first use "selection" rule and then "action". Sometimes the action behaviors have sequence to complete complex operation.

Map generalization is a decision-making process. Generalization decisions involve the determination of geometric thresholds, generalization operators, the sequence of operations and other domain knowledge, which are the essence and foundation of map generalization. During the design of software, we formulate and specify generalization regulations according to the map specifications depended on the scales of source and target database, and integrate with the characters of large-scale urban spatial database. Generalization rules are described in hex-tuple.:<layer code, attribute code, operation algorithm, item index, min value, max value>. For example, <B, 32029, JOINT, FLOOR-DIFF, 0.00, 50.00> in figure 8 represents that the buildings which are in building layer and whose code is 32029 can be joined (merge) together if their floor high difference is no more than 50 meters. The hex-tuple of generalization regulations is the core of map generalization, the bridge of data model between source and target database, and the trigger of generalization decisions. Generalization rules determine the creation of spatial objects in database, and seldom deal with spatial relationships.

Generalization rules play determining role in object creation in spatial database, which emphasize map model generalization and deal little with spatial relationships. Generalization rule is the key principle of cartographic generalization. When processing cartographic generalization, generalization rules of semantics, such as classification information, will also be taken into account. For example, in parcel generalization, when the area and the length of the parcels satisfy the generalization rules and the difference of semantic information isn't large, we generalize them.

4. KNOWLEDGE REPRESENTATION OF CARTOGRAPHIC GENERALIZATION BASED ON MODELS

Knowledge can be considered as a model of world outside, or to be precise, a model of a special field. As for cartographic generalization models, the structure and function of cartographic generalization can be expressed by a group of facts and relationships of them. When solving complex problems, such as the expression of structural knowledge in cartographic generalization, knowledge representation based on models becomes very important.

According to the understanding and cognition level of generalization comprehension, together with the generalization process of cartographic generalization, knowledge models can be separated into deep model and shallow model (Karp,1989). Deep model, called cartographic model generalization or model generalization, is the basic principle of the generalization field, referring to a knowledge model which reduces the information of maps in essence, Model generalization aims at gaining the more general and more abstract map model depending the target scale, which needs discard the secondary map objects or classes, simplify the detail levels and compress spatial relationships of geographic objects and reduce the classification and level of objects. Model generalization transforms the database of source scale into the target scale, in accordance with the cartographic rules and experts' knowledge, and there are many generalization operations related, such as selection/deletion, reclassification, typification, topological operation. Shallow model is focusing on special problem of cartographic generalization. It occurs at graphic representation level for readability and gestalt constraints. It depends on the map's display and visualization, needs symbols library support and should process the conflicts of the symbols displacement, such as knowledge model of graphic generalization, map layout and configuration. The boundary between two models is not rigorous distinct but relative; sometimes, the intersection of them occurs. There are close relationships between these two models: deep model is the basic and principle of shallow model, and shallow model is the continuity and extent of deep model and they are auxiliary to each other. There is still one thing to be illustrated: these two models knowledge include both factual knowledge and experts' knowledge and experience, the difference between which is not the same. The majority of deep model is experts' knowledge, while shallow model pay more attentions on quantification description and expression.

In traditional manual cartographic generalization, deep model refers to the comprehensive knowledge and experience of the cartographer with his long-year working experience; while shallow model refers to the concrete operations of cartographic generalization.

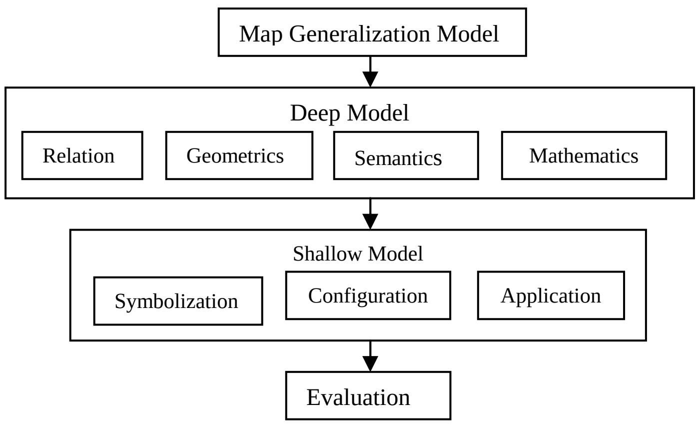

Figure 1. Knowledge model of framework of map generalization

During manual generalization, different cartographer may made different decision because of personal experience, intuition and the circumstance, and then conduce map generalization with his own method. Modeling the knowledge of cartographic generalization is beneficial for computer automation, which of course needs the formalization of models.

According to the spatial relationship, geometric shape and semantic description of geographic information, we can divide deep model into three parts: spatial relationship module, geometric module and semantic module(Ying et al 2002; Giuliana Dettori, Enrico Puppo, 1998). Spatial relationship module is used to describe the basic spatial topological relationship and basic spatial relationship transformation of objects in spatial database; geometric module deals with the computation of transformations of graphic shape; semantic module is the knowledge of classification, generalization rules and generalization decision. Besides, mathematic model about geo-info transmission concluded from the experience and knowledge of experts, is an important part of deep model plays an important role to assess of cartographic generalization. These mathematic models most refer to the knowledge and experience of quantity, area load, classification of geographic objects, such as square root law, equal ratio model, regression model.

Shallow model is located at the outside layer of cartographic generalization, mainly focusing at knowledge representation which is relevant to consumers and application, including graph simplification and configuration, symbol allocation, map layout and compile. Graph generalization is a transform from one display state to another based on a map model and modify the graph in accordance with aesthetics and Gestalt. Map display and output mostly depend on map symbols, which need the support of symbol library.

The division of the two knowledge models of cartographic generalization both makes it convenient to develop the software of map generalization system, and benefit the geo-product market. Deep model that emphasizes on the process of data and information is the first thing that geographical data suppliers take into account; while shallow models which focuses on application can be altered with the request and hobby of consumers.

With the analysis of knowledge representation models of cartographic generalization stated above, we can develop the framework of automatic cartographic generalization system based on models, which is made up of several parts: interface, knowledge capture and edition, knowledge rules database, deep models, shallow models, spatial database and assess system.

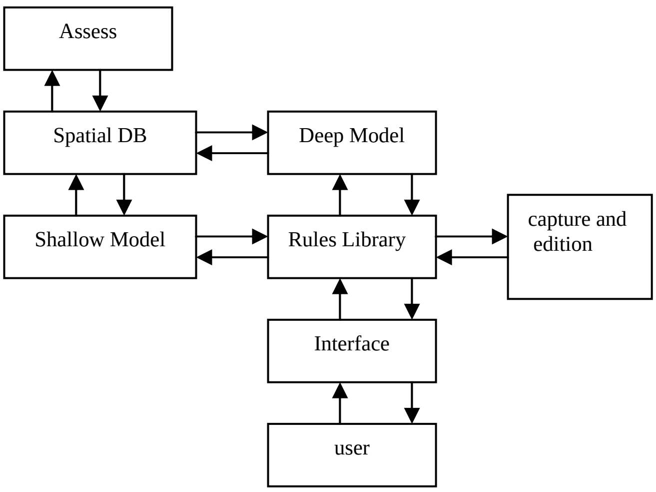

Figure 2. Map generalization system based on knowledge model

5. CONCLUDING REMARKS

The representation of geographic information based on knowledge is still a new field. Researches on knowledge system, especially cartographic generalization which needs strong professional knowledge and human decision, is still at its babyhood, which need the deep research of scholars in cartography and computer science fields.

The implementation of automatic map generalization by computers depends on the formalization representation method of cartographic generalization knowledge. Cartographic generalization, based on knowledge representation and knowledge reason, not only imitate the process of manual map generalization, but also utilize the computer formalization description. Rule knowledge representation of cartographic generalization has advantages in formalization that computers can be made to analyze generalization rules and execute generalization behaviors. While the analysis and representation of deep model and shallow model reveal the knowledge connotation of map generalization, and offer a theoretical basic of map generalization expert system. Of course, further researches are still necessary in the following field: the representation method of standardization and formalization of map generalization knowledge, and the ambiguity and flexibility of decision generalization.

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