Knowledge for expert systems in cartography

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Abstract. The aim of expert system for cartography is the transferring the cartographical expert skills to non-professionals. Expert system is a software application, which uses artificial intelligence and can reach levels comparable to human expert. The base of expert system is a establishing a knowledge base. These four activities are necessary to ensure transfer of expertise knowledge from expert to expert system, and then to the user: the acquisition of knowledge, interpretation skills, knowledge and derive the transfer of knowledge to the user. This contribution is in detail focused on the first activity - the acquisition of knowledge. Source of knowledge are experts - cartographers or written sources. In this case, the written sources are cartography textbooks, maps, and atlases. Gaining the knowledge from experts is laborious and time-consuming activity - very often is led using interview. Cartographic knowledge must be organized in the expert system as rules or design patterns (object oriented) and stored in a cartographic knowledge-base. You can easily imagine this as typical model template of a specific map. Data must be stored in base with the requisite degree of professional qualification, which is required for backward utilization in the development of deductive conclusions in the map-making process. Expert system for cartography must contain the following elements of knowledge: theory and facts of cartography, meta-knowledge, a general strategy how to assemble a map output, not least the rules and procedures of applied cartography.

Keywords: knowledge base, ontology, expert system, cartography, acquiring of knowledge

1 Introduction

Maps are used for variety of purposes that can be broadly grouped around two main roles: maps as tools for analysis, problem solving and decision making, and maps as tools for communication of ideas between people [5]. Creating cartographically correct map is a very complex process. Current computer technology plays significant role in facilitating this process, in recent years. Efforts to simplify the process resulted into a modern desktop mapping systems and GIS. This simplification caused that many map makers can avoid to consultation with cartographer.
This of course saves time and money. Extending these systems and GIS has a positive impact on the dissemination of knowledge on the production of maps, but only in a very limited extent. In other hand we still often encounter poorly designed maps, which contain inappropriate used methods, colors, and other errors. For this reason, it is necessary to create such mapping systems which don't violate the basic rules of cartography. As a first step in this process it is necessary to build cartographic knowledge base for using with expert systems for the implementation of this knowledge into mapping software. Expert systems are an accepted form of artificial intelligence. The critical component of any expert system is the knowledge base which contains facts and heuristics that represent human expert domain knowledge. Expert system knowledge representation structures vary widely. Although they include frames and semantic networks, rule-based systems are most common in many expert systems [8].

2 Inquiry of information to the expert system

The first part of construction of cartographic expert system is transfer of expert knowledge from various sources to computer form. The sources in the area of cartography are cartographers - experts,

cartographic books, maps and atlases. Knowledge acquisition and building knowledge base is a complex and time-consuming stage of expert system development which is indispensable without collaborating between experts (cartographers) and knowledge engineers. An effectively deployed expert system must do more than embody expertise. Its rule base must be complete, non-contradictory, and reasonable. Knowledge engineers employ a variety of techniques for eliciting information from the expert in order to construct a complete and consistent rule base [1].

The cooperation with cartographers – experts is considerable in some ways [7]:

- oriented interview - obtaining of facts,
- structural interview - obtaining of terms and models,
- free association - obtaining of relation between knowledge,
- monitoring - obtaining of global strategy,
- comment of steps - obtaining of derived strategy,
- dialogue of expert with users – results are interaction between knowledge and way of communication of user.

The knowledge engineer should be aware that expert knowledge is more than one kind and not all this knowledge can be acquired from one person. An interview with only one expert-cartographer can avoid some fail in expert system. Interview with group of cartographers is better. The suitable way of interview is brainstorming. There is necessary more punctually prepare interview and carefully lead interview with group of experts. There is also danger of conflicts between experts.

Other authors describes different methods how to acquire knowledge. Basic schemes of knowledge acquisition techniques are shown in Fig. 1.

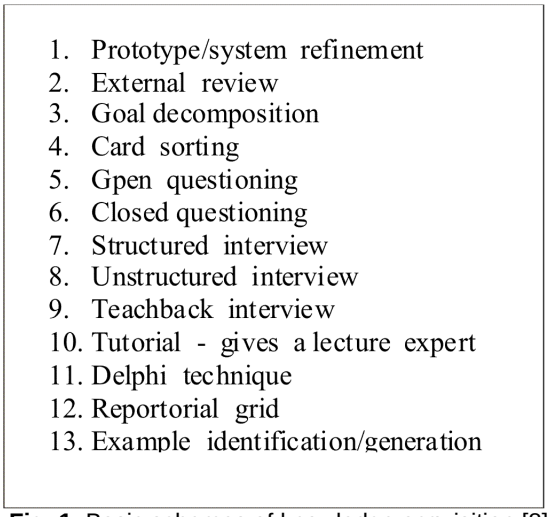

Fig. 1: Basic schemes of knowledge acquisition [8]

There are significant problems with each of these techniques, however. None of them, when used alone, guarantee consistency and integrity in the knowledge base. Since they are labor-intensive, these techniques are expensive to implement.

The phases of inquiry of information from experts are:

- Phase of concepts and formalization - inquiry of common knowledge, abstracts and terms in cartography,
- Phase of implementation - Inquiry of special knowledge and filling of base of knowledge

The *phase of concepts and formalization* is transformation of knowledge of experts to base of knowledge. The conceptual model arises in that phase. Conceptual model consists of setting of terms (entity) and relation between terms. The main task is divided to sub tasks. Examples of cartographic terms are: main theme, topographic base of map, quantitative and qualitative data and border line.
The *phase of implementation* means choice of form of representation of knowledge:

- rules and logic – suitable for shallow knowledge,
- frames and objects, semantic networks – suitable for deep and structural relation knowledge,
- hybrid systems – join of structural knowledge and inference mechanism.

2.1 Type of knowledge

The knowledge of experts can be divided to several categories: declarative knowledge, procedural knowledge, knowledge of common thinking and heuristic knowledge [6].
Declarative knowledge is expressed in terms. The terms are answers for the questions "What is it?". "*Quantitative data express amount of feature or phenomena."*
Procedural knowledge is consisted of generalize concepts as *"How to do it?"*. This knowledge is very often connected to declarative knowledge.
Knowledge of common thinking is knowledge about world that surrounding people. Older people have more knowledge of this type. "*Text and labels, which overlap in map, are worse readable.*"
Heuristic knowledge is based on intuition and personal experiences of expert with creation of map. This knowledge is tried to catch in expert system. Expert has collected and develops this experiences long time during practical work. These knowledge avoid that expert-cartographer is better in creation of map than average author of map. Heuristic knowledge is the highest level of knowledge. Expert is able create new rules for processing unique problems and specific map.

2.2 Rules

Once knowledge is acquired, whether from experts or from other sources, it must be encoded in a knowledge-representation language. Rules represent the most widely used way of knowledge representation in expert systems [2].
Declarative knowledge rules represent the invariants that can be inferred when one or more invariants hold. We can represent them by asserting a fact or facts when certain other facts are present.
Procedural knowledge rules represent the actions to take when certain invariants hold. We can represent them by calling functions when certain facts are present.

Rules are coded by IF-THEN structure which is well known from programming languages. The two means of rules can be considered: procedural and declarative.

- IF *situation* THEN *action*
- IF *assumption* THEN *result*

Procedural interpretation means that: if some situation happened, system executes action. The second interpretation (declarative) is used in diagnostic expert systems. The expert system derives result if assumption is met.
Cartographic examples of rules are:
IF line feature is river THEN set blue color for this line.
IF main theme of map is socio-geographical THEN base map contains some socio-geographical features.
IF main theme of map is physiographical THEN base map contains physiographical features.
There is necessary explanation of term „socio-geographical features“. The socio-geographical base is cities, roads, railways, district border lines etc. The explanation of term "physiographical feature" is rivers, mountains, peaks.
Rules can create chains. The results of one rule can be an assumption of other rule. The chain of rules creates structure – graph. The base of knowledge – graph does not contain cycles.

An effectively deployed expert system must do more than embody expertise. Its rule base must be complete, non-contradictory, and reasonable. Knowledge engineers employ a variety of techniques for eliciting information from the cartographer expert in order to construct a complete and consistent rule base.

2.3 Usage of ontologies

Acquiring knowledge for expert system is a very lengthy process, which is necessary to identify all the individual elements and their mutual dependence and hierarchy. Ontologies can be used at this stage of the process.
The term "ontology" has recently been adopted by the AI (artificial intelligence) community to refer to a set of concepts that can be used to describe some area of knowledge and also build a representation. Ontology can be divided into two different types. Domain ontology can be defined as a formalization of the existing knowledge in a specific domain. Domain ontologies are intended to provide a source of predefined concepts for use with task ontologies. Task ontology captures the knowledge necessary to solve a specific problem or task but abstracted above the level of a specific situation. Between ontologies exists cyclic development Fig. 2. [4].
In process of building of an expert system in cartography is necessary to build a knowledge base which will include cartographical terms and rules. The difference between ontology and a knowledge base should be explained like this. Ontology provides the basic framework or skeleton which can be used for building a knowledge base. Ontologies contain a set of concepts and terms for describing a domain. It is similar like a knowledge base uses these terms to represent what is true about some real world or hypothetical [9].

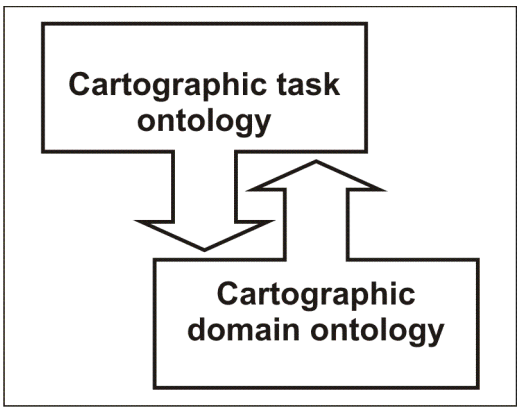

Fig. 2: Cyclic development of the domain ontology and task ontology

Like in many other professions also in cartography increase concern about ontologies, because there is an effort to reuse and share knowledge between different systems and cartographers. The development of cartographic ontologies allows cartographers and computer programs to share a common view on cartographic information and to make cartographic rules explicit and reusable. In the same time it allows to separate domain knowledge (common vocabulary) of operational knowledge (cartographic rules). They are needed as building blocks for task ontologies containing cartographic rules. From the practical point of view the development of the domain ontologies is strongly linked with identification of cartographic as the terminology needed to express the rules have to be fed into the domain ontology [4].

Transmission of this knowledge now faces the problem of mutual incompatibilities of different systems, which are used for creating and managing ontologies. Different systems use different concepts and terms to describe their domain. These differences make it difficult to access knowledge of a system to use it in another. The aim is to develop tool which will be support combining ontologies and which will allow translation each other.

3 Methodology how to build a cartographic expert system

Process of building expert system in cartography can involve certain steps. Knowledge acquisition step which involve individual expert interviews, the knowledge representation step which involve the creation of the knowledge base, knowledge validation occurred during the testing and fine-tuning of the final knowledge base.

Possible and appropriate method how to collect data can be usage of a modified Delphi method. The Delphi method [10] is a structured and iterative approach to collecting expert knowledge involving a series of interviews or questionnaires. As basement for building can be used ontologies. The plan for acquiring the knowledge and building the knowledge base had the following steps:

- have initial free-form interviews with experts;
- based on the results of the free-form interviews, develop a questionnaire to collect knowledge from a larger group of experts;
- use the data collected from the questionnaires to create a preliminary knowledge base to store and represent knowledge;
- distribute the preliminary knowledge base through the experts to fine-tune it, repeating this process if necessary;
- use available data and statistical tools to further refine the knowledge base.

The first step in developing the cartographical knowledge base should be to contact experts with experience in cartography (mostly cartographers). Since this kind of work often involves a time commitment, it is important to develop a means of motivating experts to participate in this work [3]. Motivation for the experts' participation in this work is necessary to use the results in the beta testing phase.
Once their expertise is collected, it should be implemented into a draft of knowledge base rules and stored in an if-then format. This draft should be after fine-tuned by being passed back to the cartographers for further review. From collected results should be build final knowledge base and it is necessary to test whole knowledge base for errors after finalization.

There are also other methods which can be used. Methods strictly depend on the size of knowledge base and type of acquired cartographical knowledge. One expert system is not possible due to amount of rules and facts, which should be involved into database.

4 Conclusion

Cartographic expert system is the major challenge for all cartographers from the 70's. In recent years, efforts to establish such a system, is fuelled by expanding opportunities for creating maps in the Internet environment and expansion of GIS among current users. Map creation process now doesn't require special demands on users, but the fundamental problem is correctness of the resulting map. Expert system can't be build without a knowledge base, which forms its backbone. Building a knowledge base is very time-consuming work, which requires the cooperation between experts (cartographers) and specialization in a particular area of cartography. Given the possibilities of expert systems and knowledge base is very difficult or rather impossible to create an expert system for the whole cartography. Specific expert systems may be the solution to partially eliminate errors in the maps caused by ignorance at least.

In the process of collection of knowledge for building a knowledge base is needed to accost the widest possible range of experts in the issue. It is possible to use several options. Interviews and questionnaires are used often. Very appropriating method seems to be a Delphi method. The whole process in cartography however faces problems related to the purpose, the type of map and its users. Questionnaires must be made by cartographers; therefore a comprehensive co-operation is needed at the beginning of the whole process. Knowledge engineer should have some cartographic

knowledge for better understanding the rules made by cartographers. This ability helps to facilitate to whole process.

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