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COPING WITH CARTOGRAPHICAL ONTOLOGY

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ABSTRACT

According to trends in nowadays digital cartography and the spreading of mapping software among ordinary people, it is more and more important to transfer cartographical knowledge from cartographers to computers. This process is one of the most difficult tasks for object-oriented software designers. The design of a cartographical ontology could facilitate the creation of a cartography knowledge base as a basis for an intelligent system. Captured knowledge and the knowledge base can help map users to better understand different map symbols, cartographic rules, color schemes (ramps), design layouts and to codify this knowledge into software. Specific knowledge can be then built-in in a specific user-friendly software solution. This paper describes the process of special cartographical ontology development as a base for the creation of an intelligent system for thematic mapping support with the use of expert system features.

Keywords: ontology, cartography, intelligent system, knowledge base

INTRODUCTION

The position of cartography has changed during last decades. Maps have become a tool for sharing specific knowledge among people. They are considered as a unique expression tool used for a variety of purposes. Maps have two main roles. They can be used either as tools for analysis, problem solving and decision making “visual thinking” [1], or as tools for communication between people. Good knowledge of all map making rules is expected from map makers. Knowledge of design principles can help the user to create a highly specialized view of the data. Customized and right visualized data can help users. If maps are processed correctly, they transmit spatial information accurately and quickly. If some of the rules of cartography are infringed, transfer of spatial information is inaccurate [2].

In cartography, we distinguish three main types of maps format. These are paper maps, GIS applications and the Internet mapping. They started to evolve during previous centuries in a form which was widely used and standardized. Along with the progress of GIS, the second part of modern cartography focused on the use of GIS software and visualization tools. Electronic maps and GIS digital outputs are generated by computers in a digital format which can provide an interactive, multimedia map display and dynamic spatial query functions [3]. The last section is the Internet mapping which appeared as a result of the spreading of Internet technologies. All these map stages have one attribute in common - the final map. During the map making procedure, it is necessary to have some cartographical knowledge. In contrast with this statement, there is a situation when production of a map with using this adequate software is an

uncomplicated process. To help users with cartography making and to facilitate this process, it is necessary to develop an application which would include specific cartographical knowledge [4].

Acquiring cartographical knowledge is a comprehensive process which requires specific tasks. The first stage of the whole process of the development of a software-aided cartographical tool is building up the knowledge base. Ontology can be used as a framework of the knowledge base of cartographical rules during formalization and conceptualization of knowledge into an adequate form. In this paper, we introduce the stage of design of CartoExpert ontology as a fundamental stage of a generated intelligent system for interactive support to map design.

Background and Related Work

It is a challenge for the cartographic community to make the power of present cartographical knowledge accessible to users and in the other hand to help users adapt cartographical concepts and rules to their mapping applications. From the text above, it is clear that a map making process can be done in two main ways. Firstly, users make a map from some datasets using adequate software, mainly GIS. The other possibility requires some internet mapping application like an end tool for visualizing of datasets and making maps. In both cases, it is necessary to build-in acquired cartographical knowledge into these systems. There is a need for implementation of cartographic rules directly into the programs for the map making, especially into GIS or internet based software. Despite the lack of success in the implementation of integrated digital cartographic systems into geographic information systems, the researchers still attempt to develop a framework for a complex automated map production.

The Artificial Intelligence (AI) approach in the domain of cartography has come into force in the past few decades. The first attempt to use an AI approach in cartography goes back in the 1970s [5]. In the 1980s, many cartographers tried to develop expert systems for various mapping tasks, including an automated point label placement [6, 7], automatic generalization [8], and a map label conflict detection [9]. The basic idea of the expert system is to transfer large amount of expertise knowledge of human-expert to a computer. This knowledge is then stored in the computer and users call upon the computer for specific advice. More cartographical expert systems were described in [10].

A special distributed solution of cartographical software was developed in Switzerland. QGIS map server is an open source WMS (Web Map Service) implementation. In addition to that, it implements advanced cartographic features as specified in the Map and Diagram Service specifications. With QGIS map server the content of vector and raster data sources (e.g. geotiff, shape files, gml, postgis, wfs) can be visualized according to cartographic rules (specified as request parameters). The generated map is then sent back to the client through the Internet [11].

Mapping system Common GIS [12] includes a special guide. This cartographical guide can be considered as a knowledge-based software component. Guide supports tasking and answering with cartographical procedure. The system proposes appropriate interactive techniques for accomplishing a specific data analysis and explains how to apply them. Each geo-ontology is different from other non-geo-ontologies because of the fact that topology and a part-whole relation play a major role in the geographic

domain. Furthermore, beside using geographic concepts, the Geospatial Semantic Web has other dimensions which involve space and time [13]. The idea of geo-ontology is inspirited cartographic ontology because symbols used in maps have also location and topology relations.

Well-known ontology can be found in literature and on websites for various fields of study, e.g. Protégé Ontologies Library [14]. As a starting point, we tried to find some related works for cartography, geography and related sciences. Main concepts found in related works in the field of ontology for GIS data operability [15], geo-ontology and GeoSpatial semantic web should be taken into consideration when designing a cartographical ontology.

After examination of accessible ontologies on the web and other ontological repository, we came to the conclusion that only a few particular examples of domain ontology exist in the field of cartography. There is no complex ontology which takes into consideration all aspects of cartographical knowledge. There exist some attempts to design a comprehensive ontology. This effort nevertheless collides with cartography as a whole, different cartographical schools and nomenclatures.

E. Pantaleáo presented a simple proposition of cartographic ontology in her dissertation work [16]. This ontology concerns only map symbols, variables of symbols, shape of features and category of attribute data (nominal, ordinal and numeric). There is no information about cartographic methods (graduated point method, choropleth method) and about main components (elements) of maps (map title, map area, legend, scale, and imprint).

Interesting results in cartograhical ontology development can be found in the Institute of Cartography, EHT Zurich. Their proposed cartographic ontology is centered on map concepts, graphic elements, visual variables and symbols. Furthermore, their cartographic domain ontology also focuses on the complexity of map semiotics because of the fact that different types of thematic maps (choropleth maps, graduated symbol maps, multi-variable graduated symbol maps, dot density maps, etc.) can be defined. Some details of the domain ontology such as thematic point symbols like diagrams (bar charts, pie charts, ring charts …) as well as some of their properties (divergent, divided, polar, proportional …) and some additional concepts - are arranged in their logical hierarchy [17]. All these aspects were included in their proposed ontology. The latest research at the field of cartographical ontology can be traced at University of Georgia [18]. The basic concept is similar to our CartoExpert ontology, but there are several aspects which differ.

The design of our proposed cartographical intelligent system is based on some distinct interrelated ideas: cartography, ontology and a knowledge based system. A collection of specific information is a necessary stage for final design of the expert system. The main aim is to create cartographically correct thematic maps. The best way to obtain the required knowledge is to study cartographic literature or to interview cartographers.

Thematic Cartography and ontology building

Basic pillars of the conceptualization of cartographic knowledge can be found in cartographical books. There are several basic books which deal with cartography like “Thematic Cartography and Geographic Visualization” by Slocum [19], “Cartography,

Visualization of Geospatial Data" by Kraak and Ormeling [20] and "Elements of Cartography" by Robinson [21]. Other resources are, for example "How maps work? Representation, Visualization and Design" by MacEachren [22], "The Look of Maps" by Robinson [23], and "Mapping It Out: Expository Cartography for the Humanities and Social Sciences" by Monmonier [24].

Due to different cartographical concepts and methods, it is necessary to take into considerations other authors and their books from Central Europe like "Methods of map expression" by Pravda [25] and "Application of Cartography and Thematic Maps" by Vozenilek [26]. All the rules and recommendations found- in these books and journals can be used in the phase of ontology building and knowledge base design.

Cartography defines the main division of maps. There are topographic and thematic maps. Every thematic map contains a simple topographic base map. Thematic maps represent the distribution of one or more particular phenomena [20]. Statistical data are very often marked on thematic maps. Data are divided into two groups: qualitative or quantitative data. Quantitative data are absolute or relative data. Absolute and relative data are expressed by different cartographic methods in maps. Absolute data, which have a non-area related ratio, are expressed by diagrams in maps. All methods use cartographic symbols. The creation of a thematic map, use of symbols and the use of cartographic methods are under theoretical principals and they also respect practical experience [26]. J. Pravda deeply described syntax and semantic of cartographic symbols [25]. His conclusions are important in the phase of ontology design for cartography.

Cartographical Ontology CartoExpert

The design of CartoOntology has several steps which are described in the following sections.

Names of classes are marked by expressions which clearly describe (in line with the appropriate terminology) the class in the domain and they are distinguished by individual first letters in capitals. This rule was used in order to improve the level of readability. The most important subclasses are named after their superclasses, because two classes can't have the same name. Properties of individual classes and subclasses are described in the Annotations tab to ensure the clarity of solutions.

According to several cartographical schools and approaches we decided to divide our ontology into two independent ontologies. The main concept is the same, but it is necessary to take into consideration different nomenclatures and methods which are used by these schools. Very problematic for this point of view are visual variables of map symbol.

Process of ontology building

In the first step, a set of cartography terms was acquired from cartographic literature. Discussions with experts in cartography were also inspiring. The cartography lexicon was gathered into a dictionary with descriptions and term properties. The dictionary also contains a list of synonyms. In the dictionary pruning stage, a pair wise comparison between cartographic terms and their descriptions was formed from the lexicon set.

Synonyms of terms were grouped together, and one particular description was chosen to represent the term.

Authors of the ontology had to understand all kinds of relations (such as is-a, part-of) between individual concepts. Combining the characteristics of cartography concepts, relations as classification relation, concept-semantic relation and concept-attribute relation in CartoExpert ontology arose. Basic view and main elements of ontology are described follow:

- Data – data characterization (main subclasses: Qualitative Data, QuantitativeData) GeometricCharacterizationOfMapSysmbol - localizaton, anchoring of symbol in the maps (main subclasses: PointLocalizedSymbol, LineLocalizedSymbol)
- Geometric - geometry (main subclasses: PointGeometry, LineGeometry, PolygonGeometry)
- ValueOfData – data from view of relative/absolute value (main subclasses: AbsolutValue, RelativeValue)
- Phenomenon (main subclasses: PointPhenomenon, LinePhenomenon, ArealPhenomenon)
- MapComposition (without subclasses)
- LayoutElement – main and secondary layout elements (main subclasses: Diagram, Graph, Legend, MapBody, ScaleBar, Picture, NeatLine, Nort Arrow, Table, Imprint, Title, SecondaryMapBody)
- MapSymbol, (main subclasses: PointSymbol, LineSymbol, PolygonSymbol)
- Method
    - QualitativeMethod
        - PointFeatureMethod
        - LineFeatureMethod
        - ArealMethod
    - QuantitativeMethod
        - CartogramMethod
        - ChoroplethMethod
        - DasymetricMethod
        - DotMethod
        - GraduatedSymbolMethod
        - IsarithmicMethod
        - PieChartMethod
        - ProportionalSymbolMethod
- Projection
- SymbolVariables (main subclasses: Color, Outline, Orientation, Texture, Thickness, Shape, Size, Structure)
- DataComponent - (main subclasses: AttributeComponent, SpatialComponent)
- Coordinate system
- Scale (main subclasses: FunctionalScale, IntervalScale)
- AreaOfInterest (main subclasses: TerritorialUnit)

For incorporating taxonomy we used possibility of Protégé editor to use property editor to specify individual relationships between terms in ontology (Fig. 1).

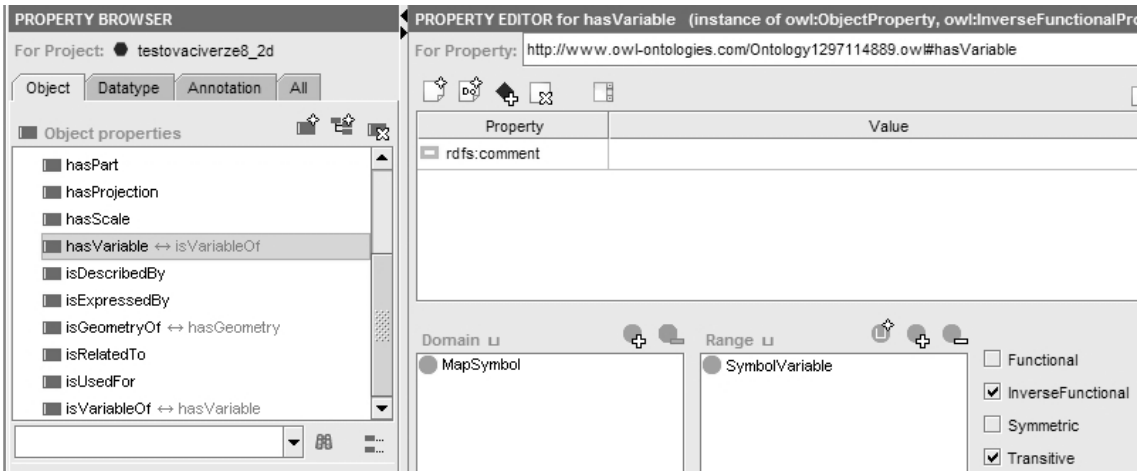

Fig. 1 List of object properties in Protégé (properties "hasVariable")

Transferring ontology into expert system

The whole idea of cartographical expert system is based on utilization of ontology as a primary framework for the knowledge base of cartographical rules. Domain model transformed from ontology will be transferred into an expert system with using JAVA classes. System DROOLS was chosen as the expert system for final implementation of rules based on complex testing [27]. Particular instruments were individually tested with regard to possibilities of formalization of the rules applicable to an interactive guide of thematic maps creation, as well as with regard to the clarity of language of formalized rules for the inserting by a specialist, cartographer without deeper knowledge of programming. Practical testing of a class transfer, from owl ontology to the expert system, was a key point of the whole implementation. Many approaches were tested during the process of acquiring knowledge about transferring the ontology into JAVA classes. Protégé OWL-API, RDFReactor and Owl2Java were chosen for practical testing of transfer.

Conclusion and final remarks

We have presented some criteria for the cartographical ontology. Developing a cartographical ontology is not an easy task. During the conceptualization phase, it is necessary to take into consideration many factors such as new trends in the field of cartography and new approaches in neocartography. This reflects the fact that an ontology development in this domain is based on the point of view of experts involved and cartographical schools. It is necessary to establish some cartographical ontology framework from which a similar ontology could develop. With regard to future development, we are attempting to accumulate deeper cartographical knowledge and to build-up a coherent cartographical ontology. The main aim is to develop an ontology which can be considered as complex in at least one cartographical sub-domain. The whole process of ontology development is the peak of the proposed expert system which can help users with specific tasks in the field of cartography. This system should implement specific cartographical knowledge. It should also serve as a useful guide in thematic cartography. The proposed expert system can be built in some software with

GUI or can be build-up like a text guide. Question – answer concept can be problematic due to necessary basic knowledge of the potential user. Finally, the proposed ontology seems to be a very good example of incorporation of specific knowledge into a coherent form. On the other hand, there is still a lot of work and future development. To propose a more coherent ontology and to cover more sub-domains, it is necessary to cooperate with the whole cartographic society.

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REFERENCES

1. MacEachren, A.M., Kraak, M.-J.: Exploratory cartographic visualization: advancing the agenda. Computers & Geosciences, 23(4): pp 335-343. 1997
2. O'Looney, J.: Beyond maps: GIS and decision making in local government. Redlands, California: ESRI Press. 2000
3. Tsou, M-H.: An Intelligent Software Agent Architecture for Distributed Cartographic Knowledge Bases and Internet Mapping Services. In Maps and the Internet, M. Peterson (ed.), Oxford: Elsevier Press, pp 229-243. 2003
4. Dobesova, Z. Valent, T.: Program Extension for Diagram Maps. Geodesy and Cartography, 37(01), Taylor & Francis, 2011, pp 22 - 28. ISSN: 2029-7009 doi: 10.3846/13921541.2011.558330
5. Openshaw S. & Openshaw C.: Artificial Intelligence in Geography. New York: John Wiley & Sons, Inc. 1997
6. Christensen, J., Marks, J., & Shieber, S.: An empirical study of algorithms for point-feature label placement. ACM Transactions on Graphics 14(3), pp 203-232. 1995
7. Doddi, S., Marathe, M.V., Mirzaian, A., Moret, B.M. &Zhu, B.: Map labeling and its generalizations. In Proceedings of the 8th ACM-SIAM Symposium on Discrete Algorithms, pp 148-157. 1995 URL: http://www.cs.unm.edu/~moret/map.ps
8. Buttenfield, B.P. & Mark, D.M.: Expert systems in cartographic design. In Geographic Information Systems: The Microcomputer and Modern Cartography, ed. D. R. F. Taylor, Oxford: Pergamon Press. pp 129-150. 1991
9. Robinson, G., Jackson, M.: Expert Systems in map design. Proceedings AutoCarto 7, Washington D.C. 1985
10. Brus J., Dobesova Z., Kanok J. Utilization of expert systems in thematic cartography International Conference on Intelligent Networking and Collaborative Systems, INCoS, 2009, Barcelona
11. QGIS Mapserver, 2010. http://karlinapp.ethz.ch/qgis_wms/index.html
12. Andrienko, G., Andrienko, N., Voss, H. Computer cartography and cartographic knowledge. Proceedings: Intercarto 8, International Conference, Saint-Petersburg, Russia. St. Petersburg, pp. 114-117. 2002

13. Fonseca, F., Rodrigues, A.: From Geo-Pragmatics to Derivation Ontologies: new Directions for the GeoSpatial Semantic Web, Transactions in GIS 11(3), 2007, pp. 313–316.

14. Protégé Ontologies Library. http://protege.stanford.edu/ontologies/ontologies.html.

15. Stanimirovic, A., M. Bogdanovic, et al. "Mapping Ontologies to Object-Oriented Representation in Geonis Framework for Gis Interoperability." 10th International Multidisciplinary Scientific Geoconference: Sgem 2010, Vol I: 1127-1134

16. Pantaleáo, E.: Aplicacáo de técnicas de sistemas baseados em conhecimento em projeto cartográfico temático (Application of techniques for knowledge based systems in thematic cartography), disertation thesis, Universidade Federal do Paraná, Curitiba, Brasil, 2003

17. Enescu, I.I., Hurni, L.: Towards cartographic ontologies or how computers learn cartography, In: Proceedings of the 23rd International Cartographic Conference, Moscow, Russia, 2007

18. Smith, A. R.: Designing a cartographic ontology for use with expert systems. A special joint symposium of ISPRS Technical Commission IV & AutoCarto in conjuction with ASPRS/CaGIS 2010. Orlando, Florida 2010.

19. Slocum T., McMaster, R., Kesseler, F., Howard, H.: Thematic Cartography and geographic Visualization, Prentice Hall, 518 p. 2004

20. Kraak, M., J., Ormeling, F.: Cartography, Visualization of Geospatial data, Second Edition, Prentice Hall, London, 2003

21. Robinson, A. Morrison, J., Muehrcke, P., Kimerling, A., Guptill, S.: Elements of Cartography, John Wiley & Sons, INC., USA 1995

22. MacEachren A., M.: How maps work: representation, visualization, and design, The Guilford Press (2004)

23. Robinson, A.: The Look of Maps. Madison: University of Wisconsin Press, 1952

24. Monmonier, M.: Mapping It Out: Expository Cartography for the Humanities and Social Sciences, The Univesity of Chicago Press, 1993

25. Pravda, J. Metódy mapového vyjadrovania, Klasifikácia a ukážky, [Methods of map expression, Classification and examples], Geographia Slovaca 21, Slovak academy of sciences, Geographical institute, Bratislava, 2006, (In Slovak)

26. Vozenilek.V.: Aplikovaná kartografie I., Tematické mapy, [Application of cartography, Thematic maps], Publishing house of Palacký University, Olomouc (2004) ISBN 80-224-0270-X (In Czech)

27. Brus, J., Dobesova, Z., Kanok, J., Pechanec, V.: Design of intelligent system in cartography. In Brad, R. (ed.): Proceedings. 9 RoEduNet IEEE International Conference. Sibiu, University of Sibiu, pp 112-117 ISSN 2068-1038. ISBN 978-1-4244-7335-9. 2010