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# Intelligent Systems in Cartography

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## 1. Introduction

According to the recent progress and technical development in Geographic Information Science (GIScience) [Kraak, MacEachren, 1999], and in information technology we can trace the progressive significance of the role of maps, images, and computer graphics as mediators of collaboration - in a range of contexts including environmental and urban planning, resource management, scientific inquiry, and education [Brewer et al., 2000]. Maps became a tool for sharing knowledge around people. They are comprehended as a unique expression tool used for a variety of purposes that can be broadly grouped around two main roles: maps as tools for analysis, problem solving and decision making "visual thinking", [MacEachren, Kraak, 1997], and maps as tools for communication of ideas between people. Although the communicative role of maps seems to fully comply with the cartographic tradition, it should be borne in mind that the concept of cartographic communication has recently extended [Andrienko, Andrienko, Voss, 2002]. Maps are unique means for communication of adequate amount of spatial information. Visualizing allows us to grasp and retain larger amount of information compared to the usage of words. Without the visual image, recalling the same information would require memorizing a long list of area descriptions [O'Looney, 2000].

If the maps are processed correctly, they transmit spatial information accurately and quickly. If some of the rules of cartography are violated, communication of spatial information is inaccurate. The communication of spatial information is sometimes completely wrong. Subsequently, the map-reader can be significantly affected by the result of representation of information. From the other point of view, badly understood map may have fatal consequences in crisis management when transferring of the right information between collaborating people is necessary. In this context, map plays the role of symbolic operator able to act in such a decision making, characterized by urgency and criticality.

Thus, the good knowledge of all the rules for maps making is expected from the map maker. Knowledge of design principles can help the user create a highly specialized view on the data. Customized and right visualized data can help viewers identify patterns, which can be lost when using the un-adequate method [O'Looney, 2000].

Map making process can be done in two main ways. Firstly, the users make map from some datasets using adequate software. The opposite situation requires map server as end tool for visualizing of datasets. In both cases is necessary 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 software.

The usage of intelligent systems has been enabled by the development in the field of artificial intelligence. Therefore, these systems find application in many sectors of cartography. Real cartographer can be partly substituted by the utilization of knowledge system (intelligent system).

## 2. Cartography and intelligent systems

Computer-assisted thematic cartography has been highlighted in the forefront of interest by the following development in the field of GIS and map making but also thanks to the expansion of improper map-making. Usage of different methods in thematic cartography is very dependent on the specific type of map, user and the resulting information. Cartographer accesses very often at this stage and determines what is appropriate and what is not. The possibility of intelligent system usage can be found in that stage.

Quantity of used thematic cartography methods, different types and quality of input data and other factors, however, can cause problems. The creating of a high-quality and comprehensive system for thematic cartography is extremely complex task. The main idea of designing the decision-making support system in thematic mapping is using all kinds of technologies and methods. The aim is to solve the decision-making problems in thematic mapping in order to make a perfect map through operating intelligent system by users [Quo, 1993]. Key decision-making issues referred to the thematic map design should be analyzed clearly at the beginning of designing a good intelligent system. Nevertheless, corresponding decision-making models and reasoning methods should be proposed according to different problems.

In order to transfer map information effectively, it must reduce the noise hidden behind the map information and prevent over much map information. In thematic cartography, there are more than 10 commonly known thematic map types, namely point diagram maps, linear diagram maps, chorochromatic mosaic maps, isoline maps, stereoscopic perspective methods, nominal point symbol maps, proportional symbol maps, dot methods (dot mapping), classification ratio method (choropleth maps), statistical maps (areal diagram methods), cartographic arrowhead methods, triangle charts law [Quo, Ren, 2003].

Various geographic data have a different structure of data. Every method should be corresponding to geographic data characteristics. Moreover, only some specific types of map graphics express specific geographic phenomena (Population Pyramid). This is the very important part of thematic cartography. Different methods will emphasize differently on different map data characteristics. Furthermore, some data characteristics can be only expressed by particular methods. When we can distinguish type of data and their structure, we will be able to know which method to choose [Andrienko, Andrienko, Voss, 2002]. We can select a different map representation according to the spatial distribution of quality, quantity, grade combined, compared, direction and temporal options.

Producers of GIS software try to incorporate sub-expert cartographic knowledge as part of the program functionality. For example, we can consider the offer of color scale as a specific program codified cartographic knowledge in ArcGIS software. A program shows

appropriate scales according to visualization qualitative or quantitative data. When a quantity type of data is selected than the predefined color scales of tones based on one color with different saturation will be automatically offered in ArcGIS. This offer is cartographically correct. However, the user can make mistakes here because bad choice scales are also offered. This mistake of choosing wrong color ramp for expression quality or quantity is represented on Fig 1. This map visualizes the different six weeks of the student vacation in the Czech Republic. This qualitative phenomenon is correctly expressed with different tone of the color (yellow, orange, light blue, green, dark blue and violet) for every week on the upper map. Wrong usage of color for expression of six weeks by graduated color ramp (colours from yellow to brown) is in the map on top in Fig. 1. This graduated color ramp can be used only for quantitative data. Light color (yellow) expresses small value, dark color (brown) expresses big value. The week of vacation is not small or big value.

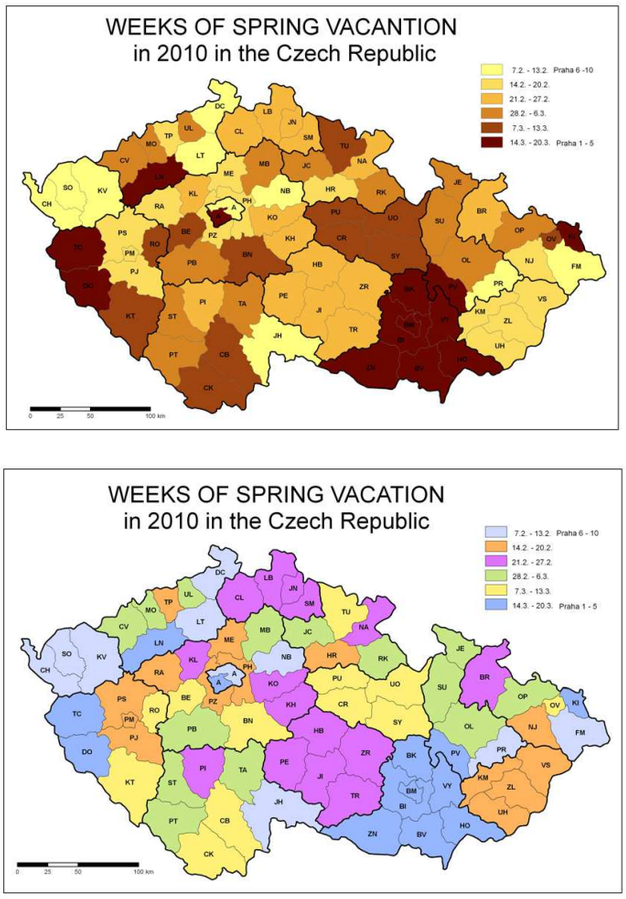



Fig. 1. Example of bad use of color ramp for qualitative data - wrong map (up) and correct map (bottom)

In developing an intelligent system, there are two related sets of problems. Transformation of existing cartographic practice into rule-based knowledge stands the first and the second is to guide the system through the map-making task. The knowledge in the domain is encoded

in the form of rules, which constitute the building blocks of the knowledge base. The application logic and the procedural information of the system are described by rules and operated on objects, classes and slots [Stefanakis, Tsoulos 2005]. The structure and organization of the knowledge base is critical for efficiency and the overall performance of the system. Only features referred to the usage of a map can be presented and, on the other hand, only important elements can be shown when there are too many features [Hua, 1991].

That is why it is necessary to include all the potential factors to the database when designing such a system, or it is necessary to focus only on some issues in a map-making process.

In disrespect of the basic rules, there may be restrictions of expressing the ability of the map or the cartographic expression becomes unreadable. Intelligent system can assist to the correct selection of colour in accordance with the rules of cartography. E.g. conservation principle of conventionality (blue colour for waters, brown colour for contour lines), conservation principle of associativity (green forests for topographic maps), the right choice of colours for the qualitative data or the correct shade of colour for expressing the intensity of the phenomenon. They can take into consideration the type of imaging methods and the people suffering from daltonism etc. There is also an art to displaying information visually, and sometimes principles contradict each other [Andrienko, Andrienko, Voss, 2002].

The basic principle of the intelligent system is to divide the whole process into subsections, which affect the result. The resulting proposed system must be coherent and comprehensive. Good comprehensive intelligent system for thematic cartography should be able to propose appropriate solutions of the problem. Excellent intelligent system should be even able to offer not only one possible solution but also give the explanation and justification to the user.

## 3. Cartographic intelligent systems with a specific knowledge

With the development of digital cartography and transfer maps to digital form there is an increasing need to vectorize and generalize properly. Both processes are widely used in the last decade. This process, however, requires the presence of expert and correction of the process. Software that directly vectorize scanned image maps can be divided into automatic and semi-automatic, depending on the modes of information processing [Hori, Tanigawa, 1993], [Eikvil, Aas, Koren, 1995]. Most of current automatic vectorial systems apply the same method for all maps and do not take into consideration their different nature. It is expected from the user as the most accurate manual setting as possible, which presupposes good knowledge of the problems and knowledge of the system used [Hori, Tanigawa, 1993]. One option is to use the knowledge base and thus reduce the overall demand of cartographic literacy of the users and facilitate the whole process of vectorization. In conjunction with the knowledge base we get a system that is able to give results very similar to the of outputs highly sophisticated manual digitization. In addition, it provides more agreeable user interface which allows the selection of appropriate parameters in accordance with the visual information contained in the original map.

Even generalizing algorithms of existing systems often ignore the role of maps or fuzzy logic to optimize the process. There are thus not able to extract hidden information. The specific knowledge, which is not taken into account in so far known algorithms, is required

[Meng, 2003]. Generalization entails a number of different rules that must be correctly applied in a certain sequence. Different roles have different rules and different knowledge base. This compilation of a dynamic system is a possible solution to the automatic generalization. In the context of digital cartography and expert systems is therefore very necessary to examine and interpret the processes at manual generalization. The overwriting the procedure of the cartographer into a sequence of a procedure of very well defined processes is a key objective in creating a successful expert system [Lee, 1994].

Implementation of the knowledge of experts to the programs for work with a map can greatly specify and simplify the whole process. Automatic generalization is interesting example. These intelligent guides can be found in different software such as ArcGIS, DynaGen and LaserScan. The development of intelligent systems is a major commercial application of artificial intelligence (AI) which is proposed to increase the quality and availability of knowledge for automated decision-making [Boss, 1991].

For common users it is much more preferable to use freely available software resources. These resources can help with the creation of maps. In the following text, there are some of these applications. The "MapBrewer" system is named after the researcher and cartographer Cynthia Brewer. It is a new type of a system developed to encourage the creation of maps. It helps the user always with only one particular aspect in the production of maps.

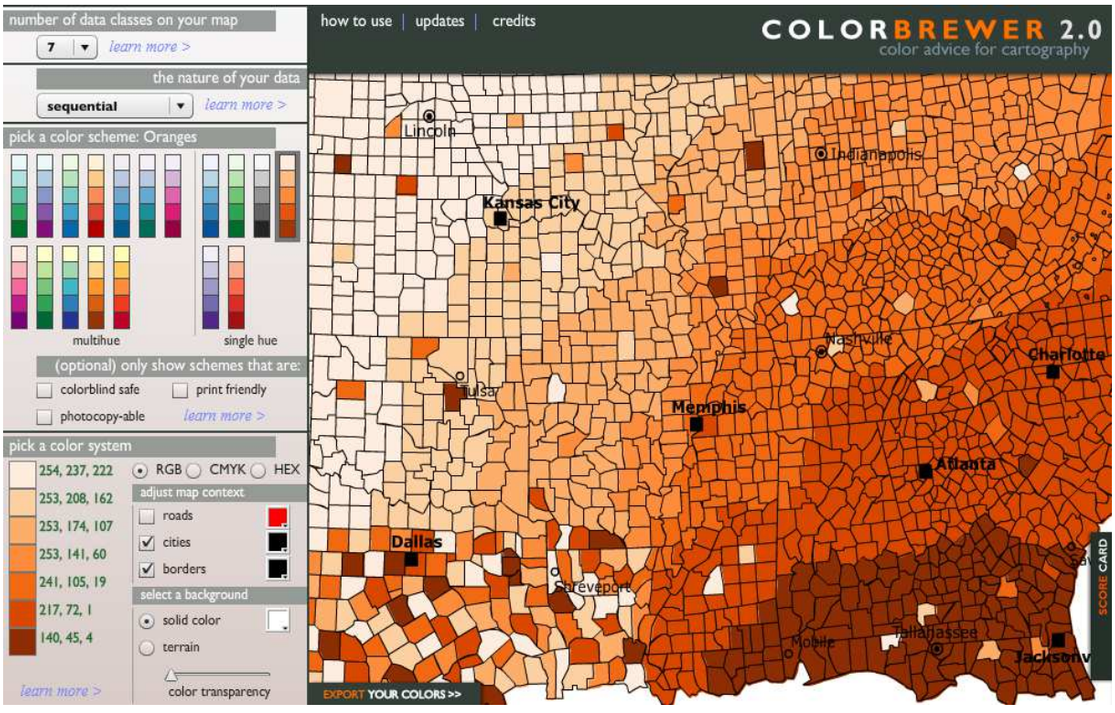



Fig. 2. ColorBrewer 2.0 – Color advice for cartography

Three versions, namely ColourBrewer [Harrower, Brewer, 2003] instrument for the correct choice of colour composition, SymbolBrewer [Schnabel, 2005] for the selection of appropriate map symbols, and TypeBrewer [Sheesley, 2006] to the appropriate font, are now available. These described systems can be rather referred as "digital teaching assistants".

They offer important theoretical background, but also user-specialist can find out solutions in them. They differ from other forms of online assistance such as wizards, tutorials, guides, forums, and others. They do not effort the user only one solution and they do not work for him without an explanation. They rather propose a user the range of possible correct solutions and seek to encourage users to think of the problem as an expert does. This activity is similar to that offered by the expert consultation. Another system belonging to a group of research applications is the expert system developed in China for decision support in thematic cartography [Zhang, Guo, Jiao, 2008]. It is the kind of a geographic information system, which helps users with the process of creating thematic maps. The system has a single interface. Through this system, you can choose the thematic elements and then it is possible to create automatically thematic maps according to the type and characteristics of their elements. User can modify the design parameters of various charts and through the interface obtain satisfactory results. This system is the unique solution of a complex expert system in thematic cartography. Special distributed solution was developed in Switzerland [Iosifescu-Enescu, Hugentobler, Hurni, 2010]. QGIS mapserver is an open source WMS (Web Map Service) (1.3.0 and 1.1.1) implementation. In addition, it implements advanced cartographic features as specified in the Map and Diagram Service specifications. With QGIS mapserver the content of vector and raster data sources (e.g. shapefiles, gml, postgis, wfs, geotiff) can be visualized according to cartographic rules (specified as request parameters). The generated map is sent back to the client over the internet. The cartographic rules handle advanced filtering and symbolisation of features. For improved cartographic representation, the data should be enriched with attributes to control rotation, scale, size or even transparency.

As a cartographical guide we can consider also a knowledge-based software component, called task support guide, that proposes the users appropriate interactive techniques for accomplishing specific data analysis tasks and explains how to apply these techniques. The guide is integrated in mapping system CommonGIS [Andrienko, Andrienko, Voss, 2002].

In addition, there is a large number of systems as an outcome of research work. These systems come from number of the world's research places but they are mostly aimed at the individual field cartography. These systems also often end just as the output of research or as a springboard for further research. From most important we can choose, MAPAID [Robinson, Jackson, 1985], MAPKEY [Su, 1992], ACES [Pfefferkorn et al., 1985] and many others.

### 3.1 Cartographical knowledge and their acquiring

The first part of construction of cartographic intelligent 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 intelligent system development which is indispensable without collaborating between experts (cartographers) and knowledge engineers. An effectively deployed 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 [Balch, Schrader, Ruan, 2007].

The cooperation with cartographers is considerable in some ways [Návrat et al., 2002]:

- 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.

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 [Okoli, Pawlowski, 2004] 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 [Booker, Meyer, 2001]. 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. The best way is using cartographical literature and combined these results with interview methods. Methods strictly depend on the size of knowledge base and type of acquired cartographical knowledge. One intelligent system is not possible due to amount of rules and facts, which should be involved into database.

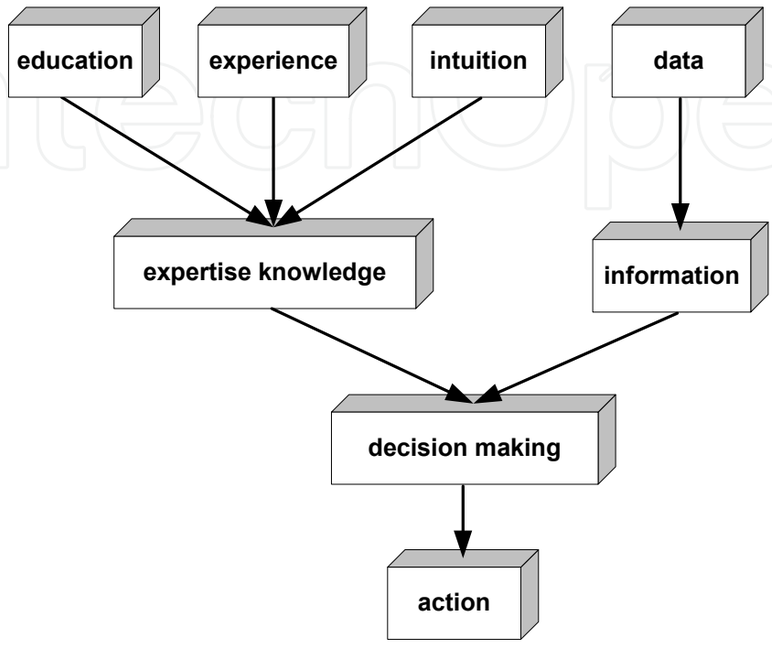



Fig. 3. The bases of expertise knowledge and expert decision making

### 3.2 Evaluation of cartographic functionality in GIS software

Starting point for design intelligent system was previous research at Palacký University in 2009 (Brus et al., 2010). This research compared possibilities of creation thematic map in various GIS software. Research was carried out to search the conditions and the possibilities of map making process in GIS software. The special evaluation method named "CartoEvaluation" has been proposed for finding out the GIS software cartography potential. New evaluation method is based on Goal-Question-Metric method. More than 13 GIS software of commercial production and Open Source Software (Czech and world-wide) were evaluated under this method. The evaluation results are summarized into complex tables and accessible at web pages of the scientific project (Dobesova, 2009).

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | G: Color schemes (ramps) (max. 40 %) | | | | | |
| | M1–5: 0 – no<br>1 – yes | Q1: Are there predefined qualitative (categorical) color schemes (various colors)? | 1 | 0,50 | 0,50 | |
| | | Q2: Are there predefined sequential color schemes? | 1 | 0,50 | 0,50 | |
| | | Q3: Are there predefined bipolar (diverging) color schemes? | 1 | 0,50 | 0,50 | |
| | | Q4: Are there predefined color hypsometric ramps (tint)? | 1 | 0,50 | 0,50 | |
| | | Q5: Can you create your own color schemes and save them for reuse? | 1 | 0,40 | 0,40 | |
| Total | | | | | 6,00 | |

Fig. 4. The part of evaluation table for evaluation of color scheme in GIS software

The results of the evaluation confirm that most of the programs achieved satisfactory basic cartographic functions. Nine programs achieved more than 50 from the maximum possible score (100%). Tested programs were ArcGIS, MapInfo, Geomedia, GRASS, TopoL, AutoCAD Map, Kristýna GIS, MISYS and OCAD. Commercial programs are among the best because they are being developed for a long time, and thus have the chance to meet the requirements of expert cartographic outputs. The ArcGIS program was the bets in evaluation.

Evaluation of programs also revealed some weak or missing cartographic functions. They are missing of some compound line (motivated line) and point symbol in symbol libraries. Programs also have insufficiencies in creating point and area diagram map (chart diagrams). Multi-parameters totalizing diagrams, comparative diagrams and dynamic diagrams are missing. Cartograms methods (anamorphosis) are very seldom implemented.

Functionality of setting colours is acceptable. It is possible to select the color from a palette in different color models (RGB, HSV). Some color schemes (ramps) are, however, missing, in particular bipolar, gradation or hypsometric color schemes. Possibility to create, save and re-use custom color schemes is very rare.

GIS software is not only aimed for creation of cartographic outputs. Cartographic outputs are in the end of GIS analyses. The overlay analyses of spatial data (spatial clip, symmetrical difference, spatial union etc.) bring new results and new spatial data e.g. for urban planning (Dobesova, Krivka, 2011). Another example of spatial analysis is the field of the spreading of diseases (Absalon, Slesak, 2011). The results of analyses are necessary correctly express in the map. The process of analyzing and cartographic outputs can be automated by data flow diagrams or by programming language (Dobesova, 2011 a, b).

## 4. Cartographical ontology

In fact, there is significant convergence of artificial intelligence and geographic information systems recently (Vozenilek, 2009). Artificial Intelligence (AI) takes many forms such as expert systems (ES), fuzzy logic, and neural networks (Ham, 1996). Two artificial intelligence methods are widely used in GIS - artificial neural networks and fuzzy logic. The position of cartographic expert system in computer science is on Fig. 5.

The development of intelligent (expert) system needs formalization of cartographical knowledge for computers “to understand” the map making process. Humans understand intuitively. On the contrary, computers need explicit coding. A design of ontology is way for coding the formal cartographic knowledge. Ontology is a formal specification of a shared understanding of a knowledge domain that facilitates accurate and effective communication meaning (Gruber 1993).

Ontologies are defined for purposes of sharing and re-use of knowledge across information systems. Specialized ontologies are aimed to design a common conceptual system - thesaurus. Similarly, the cartographic ontology defines the basic conceptual system (conceptualization) for the cartography. Cartographic concepts (classes) are formed as a hierarchy of classes with simple constraints. The cartographic ontology had to capture also the context and constraints of classes using description logic. The final target was not only the creating of cartographical thesaurus but the usefulness of cartographic knowledge in the

process of machine inference. Protégé program is often used for building of ontology. Protégé allows the definition in the language OWL-DL. This language is currently the most commonly used ontological language. The cartography is a very extensiveness discipline. From that fact, two methods were chosen from thematic cartography – choropleth method (area quantitative method) and diagram maps (cartodiagram) for the pilot stage of scientific research. Built ontology was created the necessary basis for an intelligent system that supported the users in the creation of the cartography correct maps.

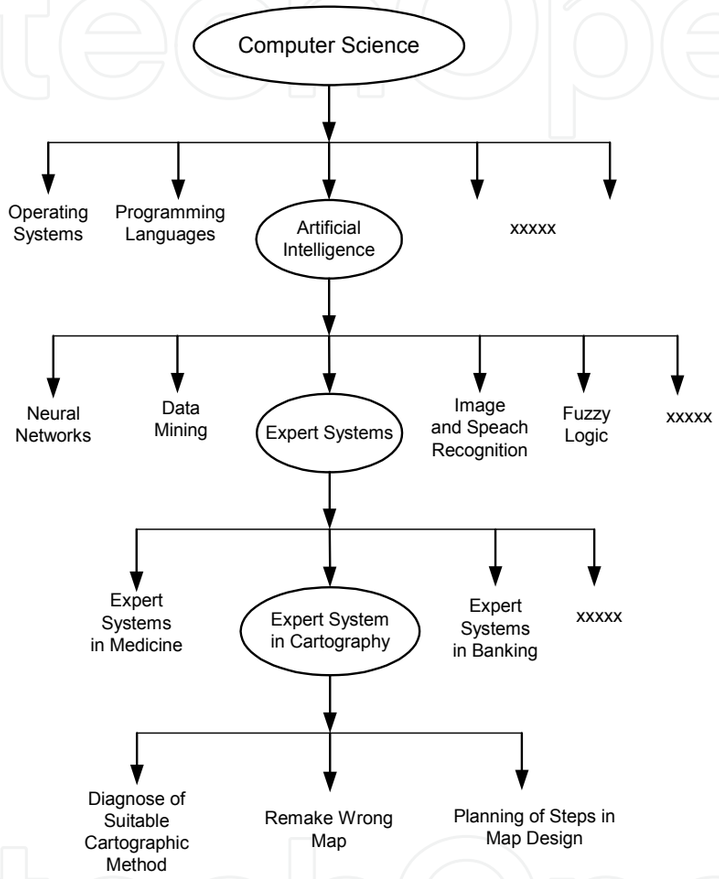



Fig. 5. The position of cartographic expert system in computer science

### 4.1 Current state of the cartographical ontologies

Well-known ontology can be found in literature and on websites for various fields of study, e.g. Protégé Ontologies Library. As a starting point, we tried to find some related works for cartography, geography, GIS and related sciences. Main concepts found in related works in the field of ontology for GIS data operability (Stanimirovic, 2010). GeoSpatial semantic web and geo-ontology should be also taken into consideration when designing a cartographical ontology.

After examination of accessible ontologies on the web and other ontological repository, we came to this conclusion: Only a few particular examples of domain ontology exist in the related field. 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 different cartographical schools and nomenclatures.

E. Pantaleáo (2003) presented a simple proposal of cartographic ontology in her dissertation work. This ontology concerns only basic class as map symbols, variables of symbols, shape of features and category of attribute data (nominal, ordinal and numeric). There are no classes about cartographic methods (graduated point method, choropleth method) and about main components (elements) of maps (map title, map area, legend, north arrow, scale, and imprint).

Interesting results in cartographical ontology development can be found in the Institute of Cartography, EHT Zurich (Enescu & Hurni, 2007). Their 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 the logical hierarchy. 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 (Smith, 2010). The basic concept is similar to our CartoExpert ontology; however, there are several aspects which differ.

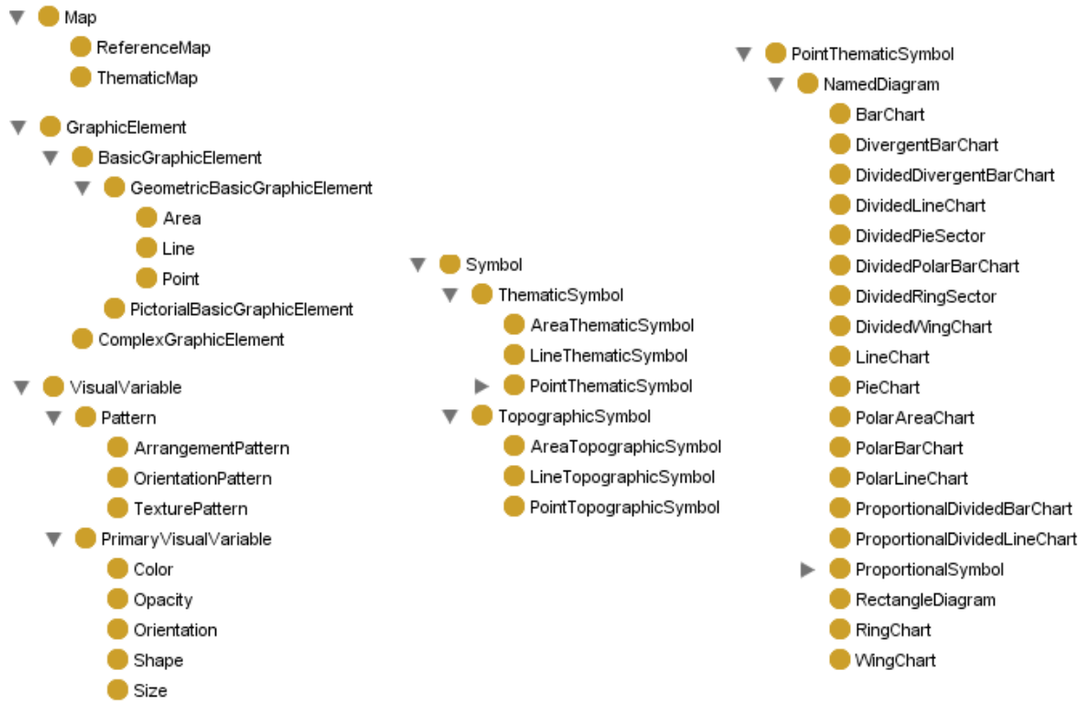



Fig. 6. Detail of domain ontology from the Institute of Cartography, Zurich

### 4.2 Ontology CartoExpert

Our research team decided to create new cartographic ontology CartoExpert in 2010. Basic terms of the conceptualization of cartographic knowledge can be found in cartographical books. There are several important books that deal with cartography like "Thematic Cartography and Geographic Visualization" by Slocum et al. (2004), "Cartography, Visualization of Geospatial Data" by Kraak and Ormeling (2003) and "Elements of Cartography" by Robinson et al. (1995). Other resources are e.g. "How maps work? Representation, Visualization and Design" by MacEachren (2004) and "Mapping It Out: Expository Cartography for the Humanities and Social Sciences" by Monmonier (1993).

Some different cartographical concepts and methods exist in Central Europe. Other authors and their books like "Methods of map expression" by Pravda (2006), "Application of Cartography and Thematic Maps" by Vozenilek (2004) and "Quantitative method in cartography" by Kanok (1992) were also considered. All terms, rules and recommendations were collected from these books. Subsequently, they were used in the phase of ontology building and knowledge base design.

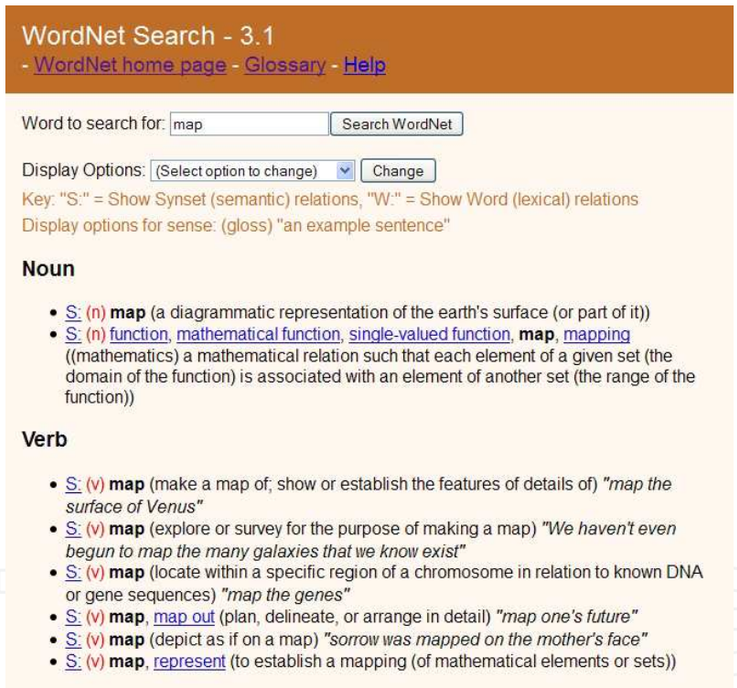



Fig. 7. The result of search for word "map" at the WordNet ontology

Maps are divided according to cartography to two main groups. There are thematic maps and topographic maps. Every thematic map contains a simple topographic base map. Thematic maps represent the distribution of one or more particular phenomena (Kraak, Ormeling, 2003). Census and statistical data are very often depicted on thematic maps. Data are divided into two types: qualitative and quantitative data. Quantitative data have absolute or relative value. Absolute and relative values are expressed by different cartographic methods in maps. Absolute values, which have a non-area related ratio, are expressed by diagrams in maps. All methods use cartographic symbols (point, line, area).

The creation of a thematic map, use of symbols and the use of cartographic methods are under theoretical principals. Additionally, creation of thematic maps also respects practical experience (Vozenilkek, 2004).

The basic terms were also compared with terminological world lexical ontology WordNet. The term as cartography, map, symbol, sign, choropleth map are included there.

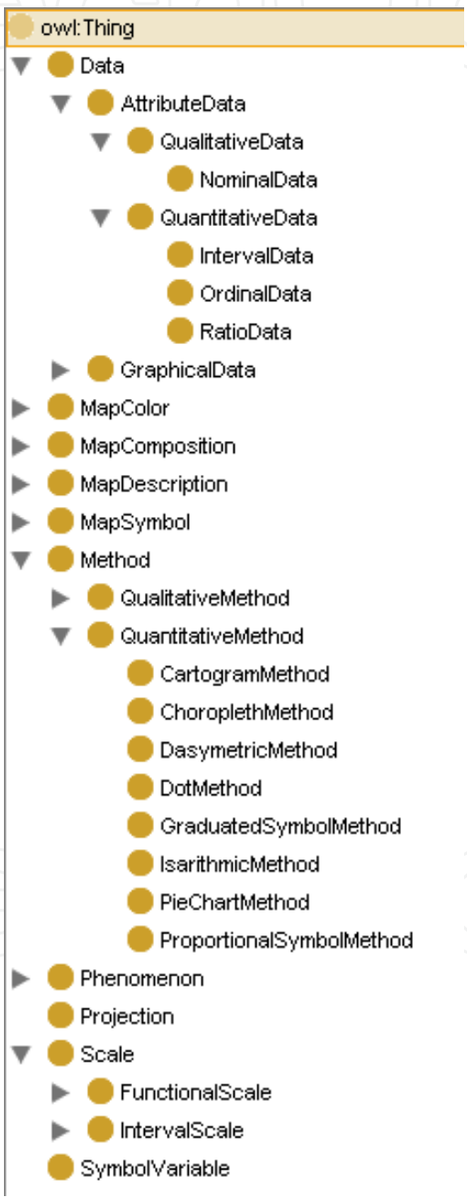



Fig. 8. The classes in CartoExpert ontology in Protégé

The base for the cartographical ontology was thesaurus – lexicon of cartographical terms. The lexicon also contained a list of synonyms. In the dictionary pruning stage, a pair wise comparison between the cartographic terms and their descriptions result to lexicon set. Synonyms of terms were grouped together. As a result, one description was chosen to represent all the synonym terms. The differences between the Central Europe and the English cartographic school were solved by the decision to design two ontologies – the Czech ontology and the English ontology. This chapter and figures describes only the English ontology for the better readability. The main classes are Data, MapColor, MapComposition, MapDescription, MapSymbol, Method, Phenomenon, Projection, SymbolVariables and Scale. These cartographic terms are expressed by **classes** in ontology in OWL language.

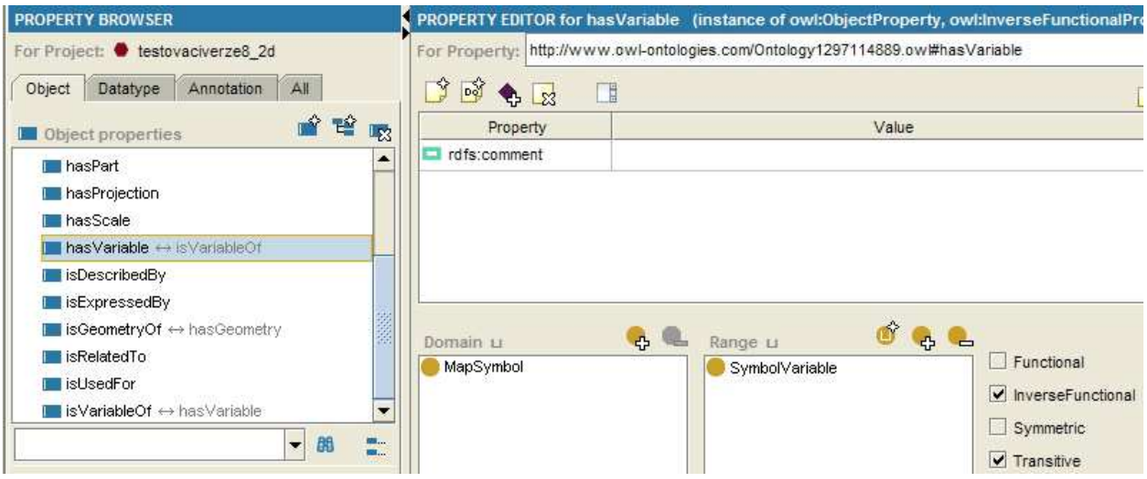



Fig. 9. List of object properties in Protégé (properties "hasVariable")

Very carefully was designed the **hierarchy** of classes. The relation of two classes is expressed by *subsumption*, *equivalence* or *disjunction*. The example of subsumption is upper class *AttributeData* and two sub class *QualitativeData* and *QuantitativeData*. The disjunction is also defined for these two classes. When data have qualitative value they can not have quantitative value. The terms isoline, isopleth and isochor are the example of equivalence (synonyms) (Penaz, 2010).

The important part of ontology is also the definition of **properties**. The property constructs relation between classes or individuals. The name of the property contains verb

**is** or **has**. The relation is set as Domain *D(f)* and Range *H(f).* The fig. 9 shows the relation between class MapSymbol and class SymbolVariable. The name of property is "hasVariable".

The main cartographic terms were necessary for the pilot project that concern only to two cartographic methods for thematic maps based on Quantitative data. The Choroplets map methods and Chart map methods are aimed. The system of the class hierarchy was designed more detailed for them than other part of the ontology. The names and division of these methods differ in the Czech and English version of the ontology. The last important class for method based on quantitative data is class Scale. This class expresses the **scale of values** (not scale of the map). This call contents two subclasses FunctionalScale and IntervalScale.

The definition of hierarchy of classes and definition of properties represent the collection of stored knowledge for the domain of cartography. Ontology gathers mainly declarative knowledge. **Declarative knowledge** is the set of definitions of terms from the specific domain – cartography. The set is not only list of terms (thesaurus) but important is grouping terms to joint classes and creation of taxonomy. **Procedural knowledge** is the second type of knowledge. Procedural knowledge describes activities and processes in map creation. This type procedural knowledge can not be introduced to ontology. They can be record as rules and such some mathematical equations.

## 5. Conclusion

Intelligent systems have already covered a range of usages, the growing trend can be traced in their development especially in recent years. The possibility of their usage is increasing with the increasing power of computer technology. It is commendable that some attempts of creation of intelligent system to force GIS have occurred recently.

Within the development, it is necessary to require the presence of thematic cartographer in the role of the knowledge expert and equally important expert - the knowledge engineer who is able to incorporate this information into the intelligent system. Knowledge acquisition and building knowledge base is a complex and time-consuming stage of intelligent system development which is indispensable without collaborating between experts (cartographers) and knowledge engineers. An effectively deployed intelligent 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.

The situation in the field of professional software is still insufficient. Even the world's largest producers of GIS software do not implement tools that should increasingly guide the process of map-making in the accordance with the cartographical rules in their products. It is still necessary to have at least basic cartographic knowledge to visualize maps properly.

So far, there has been no comprehensive tool, which can easily deal with the problem of thematic cartography completely. The main reason is the complexity and comprehensiveness of a map-making process. To build a hierarchy of rules, affect all types

of maps and the appropriate methods of thematic cartography in a single system, requires more than a comprehensive approach. Higher demands are put on the user's knowledge because he must be able to select correctly from the proposed system of options.

Despite the complexity of a map-making process the knowledge base of expert system is a solution how to help primarily non-cartographers in the production of maps according with the rules of thematic cartography towards to better decisions based on map output.

A great problem for those who tries to develop up-to-date knowledge-based software for computer mapping is the absence of systematized knowledge concerning building and use of interactive, dynamic maps. Replacing the human expert by a comprehensive intelligent system is a highly efficient objective for cartography as a whole. Not only reaching correct map, but also helping people to make right decisions is a main aim of whole cartography. Main objective will be to create a user-friendly expert system, simple and so comprehensive that will allow you to create the correct cartographic map without the need of combining more software. This software will become a popular tool for the broadest range of users. The educational potential of intelligent systems allows the extension of expertise among a large group of non-cartographers. Another advantage of intelligent system is the gradual insertion of further new expert knowledge of cartography into the knowledge base of expert system. This will quickly transfer expert knowledge between non-cartographers in the future. The elimination of the future inexpert and inaccurate maps will be achieved.

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## 7. References

Absalon D., Slesak B. (2011). The importance of time of exposure to harmful anthropogenic factors as an element of cancer risk assessment in children. *Ecotoxicology and Environmental Safety* 74, pp. 967 – 973, Elsevier

Andrienko, G., Andrienko, N., Voss, H. (2002) Computer cartography and cartographic knowledge. Proceedings: *Intercarto 8*, International Conference, Saint-Petersburg, Russia. St. Petersburg, pp. 114-117

Balch S. R., Schrader S. M., Ruan T. (2007) Collection, storage and application of human knowledge in expert system development, Expert Systems, 24 no. 5, pp. 346-355

Booker, J.,M., Meyer, M. (2001) Eliciting and Analyzing Expert Judgment: A practical guide, ASA-SIAM Series on Statistics and Applied Probability, 459 p. ISBN: 0-89871-474-5

Boss, R., W. (1991) What Is an Expert System? ERIC Digest. ERIC Clearing House on Information Resources, Syracuse, NY, 1-3.

Borst, W. N. (1997). Construction of engineering ontologies for knowledge sparing and reuse. [Ph.D. thesis]. University of Twente, Enschede, 243 p.

Brus, J., Dobesova, Z., Kanok, J., Pechanec, V. (2010) 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

Brus J., Dobesova Z., Kanok J. (2009). Utilization of expert systems in thematic cartography *International Conference on Intelligent Networking and Collaborative Systems, INCoS*, Barcelona

Brus J, Kanok, J. Dobesova, Z. (2010). Assisted cartography, vision or reality? [Asistovaná kartografie: vize nebo realita?], *Proceedings o 18th congress of Czech geographical society*, University of Ostrava, Ostrava, pp. 255-258, ISBN 978-80-7368-903-2 (in Czech)

Brewer, I., MacEachren, A. M., Abdo, H., Gundrumand, J., Otto, G. (2000) Collaborative geographic visualization: Enabling shared understanding of environmental processes. In: IEEE Information Visualization Symposium, Salt Lake City, Utah, pp. 137-141.

Dhaliwal, J. S., & Benbasat, I. (1996). The use and effects of knowledge-based system explanations: theoretical foundations and a framework for empirical evaluation. *Information Systems Research*, 7, pp. 342–362.

Dobesova, Z., Brus, J. (2011). Coping with cartographical ontology. *Conference Proceedings SGEM 2011, 11th International Multidisciplinary Scientific GeoConfrence*. STEF92 Technology Ltd., Sofia, Bulgaria, pp. 377-384 ISSN 1314-2704, DOI:10.5593/ sgem2011

Dobesova, Z. (2011a). Visual programming language in geographic information systems, *Recent Researches in Applied Informatics*, Proceedings of the 2nd International Conference on Applied Informatics and Computing Theory, AICT `11, Prague, WSEAS Press, pp. 276-280 , ISBN 978-1-61804-034-3

Dobesova, Z. (2011b). Programming Language Python for Data Processing, *Proceedings of 2nd International Conference on Electrical and Control Engineering ICECE 2011,* Yichang, China, Volume 6, Institute of Electrical and Electronic Engineers (IEEE), pp. 4866-4869, ISBN 978-1-4244-8163-7

Dobesova, Z, Krivka, T. (2011). Walkability index in the urban planning: A case study in Olomouc city, *Urban Planning,* InTech, ISBN 979-953-307-412-1

Dobesova, Z. (2009). *Evaluation of Cartographic Functionality in Geographic Information Systems*. Hodnoceni kartografické funkcionality geografických informačních systémů. Publishing house Palacký University, Olomouc, 132 p., ISBN 978-80-244-2353-1

Eikvil, L., Aas, K., Koren, H. (1995) Tools for interactive map conversion and vectorization. In: Third International Conference on Document Analysis and Recognition: 927-930.

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

Gruber, T. R. (1993). Toward Principles for the Design of Ontologies Used for Knowledge Sharing. *International Journal Human-Computer Studies* 43: pp. 907-928.

Ham, J. (1996). Artificial intelligence: building on expert knowledge, InTech, 43 (3), 52-55 pp.

Harrower, M., Brewer C. (2003). ColourBrewer.org: An Online Tool for Selecting Colour Schemes for Maps. Cartographic Journal 40 (1): 27-37.

Hori, O., Tanigawa, S. (1993). Raster-to-vector conversion by line based on contours and skeletons. In: Second International Conference on Document Analysis and Recognition. Tsukuba, Japan, 353-358.

Hua, Y., (1991) Determine the map symbol type of map element with expert system technology. Journal of the People's Liberation Army Institute of Surveying and Mapping, Vol. 3: 43-47.

Iosifescu-Enescu,I., Hugentobler, M., Hurni, L., (2010) Web cartography with open standards – A solution to cartographic challenges of environmental management, Environmental Modelling & Software, Volume 25, Issue 9, pp. 988-999,

Kaňok, J. (1992). *Kvantitativní metody v kartografii*, [Quantitative method in cartography] Ostravská univerzita, Ostrava (in Czech)

Karvaš, P. (2011). Design of knowledge base for expert system in the realative data expresion, [diploma thesis], department of Geoinformatics, Palacky University in Olomouc, 67 p., (in Czech)

Kraak, M., J., MacEachren, A., M., (1999) Visualization for exploration of spatial data. International Journal of Geographical Information Science 13:285-287.

Kraak, M., J., Ormeling, F. (2003) *Cartography, Visualization of Geospatial data*, Second Edition, Prentice Hall, London

Kasturi, R., Bow, S.T., Masri, W.E., Shah, J., Gattiker, J.R., Mokate, U.B. (1990). A system for interpretation of line drawings. IEEE Transactions on Pattern Analysis and Machine Intelligence 12 (10): 973-992.

Lee D. (1994). "Knowledge Acquisition of Digital Cartographic Generalization". EGIS, 1-20.

MacEachren, A.M., Kraak, M. J., (1997) Exploratory cartographic visualization: advancing the agenda. Computers & Geosciences, 23(4): 335-343.

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

Meng L. (2003)."Cognitive Modelling of Cartographic Generalization". Strategies on Automated Generalization of Cartographic Data, Project Report.

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

Návrat, P. Bieliková, M., Beňušková, L., Kapustník, I., Unger, M. (2002): Umelá inteligencia, Vydavateľstvo STU, Bratislava, 396 p. ISBN 80-227-1645-6

O'Looney, J. (2000) Beyond maps: GIS and decision making in local government. Redlands, California: ESRI Press.

Okoli, C. & Pawlowski, S. D. (2004). The Delphi method as a research tool: an example, design considerations and applications. Information & Management, 42, 15-29.

Pantaleáo, E. (2003) 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 de Paraná, Curitiba, Brasil.

Penaz, T. (2010) An Ontological Model Building for Application Use of Knowledge in Thematic Cartography Domain, Proceedings o 18th congress of Czech geographical society, University of Ostrava, pp. 259-265, ISBN 978-80-7368-903-2 (in Czech)

Pravda, J. (2006) Metódy mapového vyjadrovania, Klasifikácia a ukážky, [Methods of map expression, Classification and examples], Geographia Slovaca 21, Slovak academy of sciences, Geographical institute, Bratislava, 127 p. (in Slovak)

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

Guo Q. (1993) Design a decision-making support system of thematic mapping. Journal of Wuhan University of Science and Technology Mapping, 1993, Vol.18 additional: 91-9.

Guo Q, Ren, X. (2003) Intelligent geographic information processing. Wuhan University Press.

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

Robinson, G., Jackson, M. (1985). Expert Systems in map design. Proceedings Auto Carto 7, Washington D.C.

Schnabel, O. (2005). Map Symbol Brewer—A New Approach for a Cartographic Map Symbol Generator. Paper read at 22nd International Cartographic Conference, 9-16 July, at Coruña, Spain

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

Smith, A. R. (2010). 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.

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

Stefanakis, K., Tsoulos, L. (2005) Structure and Development of a Knowledge. Base for Cartographic Composition, Proceedings of International Cartographic Conference, La Coruna, Spain.

Su, B. (1992) Expert System in the application of cartographic. Journal of Geomatics, Vol. 1: 31-35

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

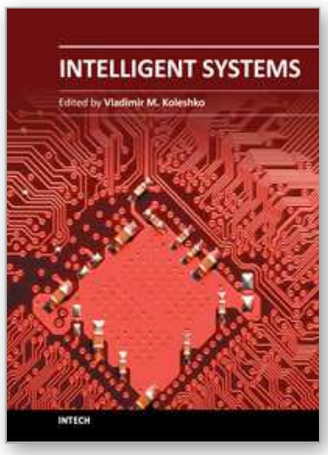
Vozenilek V. (2009). Artificial intelligence and GIS: Mutual meeting and passing. *International Conference on Intelligent Networking and Collaborative Systems*, INCoS 2009, Spain, pp. 279-284.

WordNet. http://wordnetweb.princeton.edu/perl/webwn

Zhang, L., Guo, Q., Jiao, L. (2008). Design and Implementation of Decision-making Support System for Thematic Map Cartography. The international archives of the photogrammetry, remote sensing and spatial information science. Volume XXXVII. Bejing China.

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This book is dedicated to intelligent systems of broad-spectrum application, such as personal and social biosafety or use of intelligent sensory micro-nanosystems such as "e-nose", "e-tongue" and "e-eye". In addition to that, effective acquiring information, knowledge management and improved knowledge transfer in any media, as well as modeling its information content using meta-and hyper heuristics and semantic reasoning all benefit from the systems covered in this book. Intelligent systems can also be applied in education and generating the intelligent distributed eLearning architecture, as well as in a large number of technical fields, such as industrial design, manufacturing and utilization, e.g., in precision agriculture, cartography, electric power distribution systems, intelligent building management systems, drilling operations etc. Furthermore, decision making using fuzzy logic models, computational recognition of comprehension uncertainty and the joint synthesis of goals and means of intelligent behavior biosystems, as well as diagnostic and human support in the healthcare environment have also been made easier.

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