CARTOGRAPHIC MODELING AS A FORMATION AND VERIFICATION METHOD FOR ONTOLOGIES OF GEOSPATIAL INFORMATION ON THE ENVIRONMENT QUALITY

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Introduction

At present, many cartographers and geographers feel that the narrow technological approach to the definition of a map, cartography, mapping and other concepts of this field is insufficient [Moellering 2007]. Moellering suggests that maps be classified into some types of real and virtual maps, with their forms being capable to be transformed from one into another. A classification like that has become possible with the development of geoinformation technologies and digital cartography, but Moellering [Moellering, 2007] also states that this system can embrace all kinds of spatial information, including all kinds of maps.

Hall S.S. [Hall S.S. (1992)] shows that the category "map" is extending into new areas, which results from obtaining spatial images (i.e., maps) in these new fields like medicine, biology, physics, mathematics and astronomy.

This expansion of the category "map", in compliance with the theory of family resemblance, makes it possible to expand the category "cartography" as a whole, too.

From ancient times to the present day many scientific disciplines have been using two major principles of classification:

1) categories are like containers, with things inside or outside them;

2) separate objects are considered to be in the same category if and only if they have common features.

Elenor Rosch [Rosch] , however, put the following serious questions to the classical theory of classification:

1) if categories are determined by features which are common for all its members then no member can be more representative than others;

2) if categories are determined by features which are inherent in its members then categories should be independent of the peculiarities of man-made classification (neurophysiology, perception, culture, research context, etc.)

The so-called theory of prototypes became an alternative to classical categories; one of its basic conditions is that a member of a category is determined through similarity (similarity degree) to the prototype presenting the most representative member of the category rather than through comparison to a fixed set of features.

The theory of prototypes is more effective than other models in defining the concept, place and functions of the map, the essence of this theory consisting in the following main propositions:

1. The category possesses its inner prototypical structure.
2. The degree of representativeness of a category member corresponds to the level of its belonging to the category.
3. The boundaries of categories, or concepts, are fuzzy.
4. The members of one category are united by family resemblance rather than by the features they have in common.
5. It is possible to classify any object into some category on the basis of the degree of its similarity with the prototype.
6. Researchers study material not in an analytic way, but in a synthetic, or "global", one.

Such an approach will conform to the definition [MacEachern] of the map as a radial category, one of whose diameters is the axis of scale and changes from the scale of galaxies to the that of a quark's trajectory; and the axis perpendicular to it is the axis of the degree of abstraction (or geographical similarity) of images and it changes from a photograph (a satellite picture or an aerial photograph) to a diagram. The map is between these two.

A certain part of this radial category is occupied by the category of "geoimages" [Berlyant, 2006].

The given approach, with some modification, can be also found in A.A. Lyuty who developed a diagram of the position of the map language among other language systems [Lyuty]. The specific character of the map phenomenon is connected basically with Sublanguage 1. Its means are used to represent information on the positions of objects to be mapped, on their relative positions, space forms and orientations. Means of Sublanguage 2 represent the unambiguity of the content of mapping object in maps.

According to Lyuty A.A., the map language is in "the range" between the languages of mathematical graphics and languages of graphic communications (map-like constructions, graphs, etc.).

The examples presented illustrate readily the fuzziness of the category of a map and possibilities for finding congruous similarity of a map practically with any form of information representation, including the text.

N.A. Aslanikashvili, defining the general approaches to working out the theory of cartography, notices that "… there should be some general science about the specific space of objects and phenomena of the reality in general, supplementing all other sciences in that part which they are not competent in or partially competent. This science should have as its subject of knowledge (= representation) the specific space of any combinations of objects and phenomena of the reality in any reference frame system, but it should not be abstracted from their material content as it is done by geometry, and it should be done in unity with this content". [Aslanikashvili, p. 12]

"The specific space, according to the sense of the category of space-time, has the structure undergoing time changes. The elements of this structure are as follows: the spatial extent and external form of the material objects and phenomena of the objective reality under investigation. The order of the relative positions of these elements is their specific space, and the sequence of changing of this order is the time change of this space.

According to the sense of the concept, in the specific space of each object and phenomenon, except for the spatial reference frame, there are a lot of other objects and phenomena. Therefore sciences which learn them are not completely competent to learn the specific space of the objects of their knowledge independently and separately from other sciences learning other objects and phenomena" [Aslanikashvili, p. 11].

The content of any object can be "multilateral and inconsistent", but each attribute of the content, i.e., each side of the content versatility, has its spatial-temporal extent" [Aslanikashvili, p. 22].

Peculiarities of the map language (concerning the rules of compiling maps-texts, in the terms of A.A. Lyuty's terminology), methodological and procedural tools of the cartographic method of research can have a wide application for improving the structure and content of the scientific-and-technical and analytical documentation in the sphere of nature management, environmental quality and protection, working out advanced approaches to preparing and updating regulatory-and-procedural, regulatory-and-technical, and legislative documents in the given sphere.

Kavouras and Kokla [Kavouras, M. and Kokla, M., 2007] consider maps to be ontologies, besides other aspects of map using. Ontology in philosophy as a branch of metaphysics is a science of being. It investigates into kinds of objects (abstract and concrete, existent and non-existent, real and ideal, independent and dependent) and their interrelations.

Map concepts and their hierarchy are briefly described in the map legend. The map depicts instances of these concepts.

Within the framework of the ontological approach to integration of geographic information it is offered to map one ontology or separate concepts into another ontology for ensuring information interoperability. For example, the work by Tomai and Kavouras [Tomai, E. and M. Kavouras, 2005] develops the problem of combination of classifications of various maps with the use of the situational theory and information transfer channels.

Interoperability is an ability of "systems" or "products" to work effectively and rationally together or through exchanging and repeated using of resources, services, procedures and information available according to the intent set by providers to meet the requirements of specific problems [Geographic Information, 2004, Abel D.J., et all, 1998, Laurini R., et all, 1998].

The notion of "system" concerns not only technical systems (including soft- and hardware), but also, in a more general sense, any organized sphere of people's activities (those of an organization, program, infrastructure, policy). Thus, it can also comprise interoperability of administrative services, financial systems, political systems, legal systems, etc.

Non-homogeneity (heterogeneity) can be of natural character and caused by various scales of processes, objects and phenomena, by their quality parameters or peculiarities of the technologies and methods for their research (the latter can be partially overcome) and of artificial character which is resulted from the absence of coordinated processing and representation of information on interconnected processes and phenomena.
Environmental pollution is characterized by a complex spatial-and-component structure, therefore it can be studied most effectively only with the use of the cartographic method of research.

Gathering information on the mapping object and / or phenomenon under investigation is a stage that precedes map creation. At this stage, it is necessary to study in detail not only quantitative, quality characteristics of the phenomenon and their spatial differentiation (and it is actually the subject of mapping), but also the features of the genesis, behavior and, which is of great importance, the methodological and procedural peculiarities of research and estimation of the given phenomenon within the limits of the corresponding and, as a rule, highly specialized field of knowledge. For this purpose it is required to be familiar with both science-and- methodological literature describing the methodology and methodological base for carrying out investigations, and actual results of studies made.

Then, on the basis of the information collected, and in view of the features of the territory to be mapped, scale and map purpose, the mapping technique, the systems of conventional sign and generalization peculiarities, as well as that of classification principles of phenomena to be mapped, etc., should be chosen.

Studies of created maps can facilitate revealing some new spatial and other peculiarities of the phenomenon we are interested in.

At present, mapping of environmental pollution problems is carried out in two basic ways. They are either cartographic depiction of the results of investigations made, or study management for creating maps of certain themes, territorial coverage, scales and purposes. In the latter case, there are obviously more possibilities for maximal accurate depiction of the phenomenon of interest as research programs are usually “conditioned”, in many respects, by the legend project of the map to be created, and information streams are formed in accordance with “mappability” requirements of the information collected. In the first case, on the contrary, it is necessary to search for optimum ways of representing already generated arrays of original information sometimes generalized substantially in comparison to primary data. New directions of the cartographic method development might be found in this area, making it possible to analyze and interpret information more profoundly.

Maps as ontologies of geospatial information

The peculiarities of a map as ontology, according to the author, are the following:

1. representation of spatial differentiation as the basic purpose and condition of map creation (in the case of its absence there is no necessity of map creation);
2. localization of objects and phenomena (their geographical co-ordinates, position in space-time, relative position and combination of objects and phenomena in space);
3. spatial extent (the extent of territory);
4. spatial granularity (the size and rank of territorial units);
5. time extent (the averaging time or what time instant the map is created as of);
6. time granularity (presence / absence and detail of display of changes of processes and objects);
7. thematic extent (the system of objects and phenomena mapped, the parameters of their state);
8. thematic granularity;
9. geometric accuracy (distortions of line lengths, shapes, areas, which depend on the chosen mathematical basis) ;
10. formal selection and generalization criteria of objects to be mapped (they are determined by the context of the map purpose and that of the peculiarities of the phenomena to be mapped);
11. methods for representing (cartographic imaging techniques, visual variables) objects and phenomena;
12. conceptual topological unity of the content (geographic similarity).

Spatial differentiation implies a distinction between qualitative and / or quantitative characteristics of objects and phenomena of continuous and discrete distribution at various points of observations and regions.

Localization of objects and phenomena is closely connected with spatial differentiation as the differentiation of objects and phenomena locations in the accepted system of co-ordinates and relatively to each other makes the basic component of spatial differentiation. In cartographic representation of information it is spatial differentiation that plays a leading role, through the lenses of which the differentiation of other characteristics is looked at.

Spatial extent means that there are available clear-cut boundaries and, consequently, it can be referred not only to the field of mapping as a whole, but also to separate territorial units (grains) within the boundaries of a map.

Spatial granularity characterizes the sizes of localities of the earth's surface (or those of projections to the earth's surface) for which the characteristics of the phenomena under investigation are assumed to be equal. Subject to the research objectives, the sizes of these localities (or spatial extent: in the case of differentiating localities on the basis of administrative territorial division, landscape-geographical zoning) can vary from the sizes of a sample to the territory of a whole country. If the sizes of territorial units are substantial, the localization of objects and phenomena under analysis within these territorial units can be specified additionally. For example, "the intensity of application of chemical means of plant protection on agricultural lands", "the average population density of lands attached to settlements", "specific pollutant emissions from the territories of settlement lands". In this case localization is characterized implicitly or conceptually, and an additional specification of localization of the corresponding category, or its place (like its share) in the general structure of lands within the territorial unit is required.

Time extent defines the time period throughout which the information represented on the map has been collected. In the limiting case, this period degenerates into a certain time instant (for example, in the ideal case of making maps from separate photographs).
Time granularity is another time measurement of geospatial information. It describes the detail change of the objects and phenomena characteristics with time throughout the period when the information to be mapped was being collected. The upper limit of time granularity depends directly on the measuring scale and cannot be less than the observation time interval. The bottom limit of time granularity cannot be more than the time extent of the information to be mapped. So, for instance, it is impossible to represent the variation of pollutant concentration in the atmosphere air throughout the day with sampling frequency of only once per day. At the same time, it is impossible to display the change of average annual concentrations when you have only a one-year observation time extent.

Thematic coverage characterizes the list of objects and phenomena (real and constructed ones) shown on the map as well as that of the parameters of their states.

The concept of thematic granularity is referred to classification signs of objects and phenomena, the sizes and quantity of the intervals of quantitative sign scales.

The issues of geometric accuracy, distortion of areas, line lengths, and angles on maps are the subject that is studied by mathematical cartography.

The criteria of selection and generalization of objects to be mapped are implicitly set by the map purpose, and they are detailed in an explicit form in instructive and methodological instructions on compiling maps. Besides, these criteria are influenced by the features of objects and phenomena to be mapped.

The issues of constructing map sign systems, those of implementing various techniques for cartographic representation and graphic variables, are studied well enough within the limits of cartographic semiotics.

The conceptual topological unity of map content implies a spatial and cause-and-effect coordination of showing interconnected objects and phenomena, including the coordination regarding the level of spatial representation detail, time coverage and time detail, thematic coverage and thematic detail, selection criteria and generalization methods for the information on corresponding objects and phenomena.

It is obvious that a real map can fail to meet the ideal set scheme's requirements in any of the listed above items. For instance, there might be unequal accuracy of determining the positions of objects; thematic extent can differ a little in different regions (there might be different lists of the environment quality indicators); criteria for information selection can be not strictly formalized in view of the uncertainty of requirements to the map, etc.

In the end, the result of cartographic representation of any process or phenomenon is revealing the pattern ("picture") of the placement of this phenomenon in space and time and the use of the knowledge obtained for some purpose or another.

The implementation of the cartographic method of research as a method for formation, verification and correction of ontologies of spatial objects and phenomena is one of the most perspective directions of research in the field of estimating the environment quality, planning and accomplishing nature protection measures.

It is most effective to form ontologies in a multidimensional information field, with the areas of interest outlined and the most informative projections of data representation chosen.

Formation of a new approach to the environmental impact evaluation or the environment quality can become an important application of the cartographic ontology in order to perfect and modernize present nature protection activity. The approach should consist not only in the binary system of calculation (admissible / inadmissible impact, standard permitted level of pollution /above standard permitted level) although this kind of approach also has its scope of application. The novelty of the approach offered consists in a continuous quantitative intensity assessment of the influence on the environment ingredients or the environment quality in the context of spatial localization of objects and subjects of influence in order to substantiate the priority of nature protection actions under the conditions of limited financing as well as other types of support for administrative decision-making.

Criteria of an "ideal" map

We have pointed out as criteria of an "ideal" map, which can become a basis for verification of geospatial information, the following:

- the conformity of a cartographically simulated and represented spatial differentiation of a phenomenon with the real spatial variability of this phenomenon at the chosen scale;
- theconformity of the localization / the description of localization of a phenomenon on the map / in other source of geospatial information with the true localization of the phenomenon (or the data obtained as a result of observation of the phenomenon) in a locality at the chosen scale;
- the identical accuracy of localization of interconnected processes and phenomena;
- the choice of spatial extent in order to represent the whole range of spatial differentiation of the phenomenon under investigation to the chosen scale and analyze the phenomenon in the territory of interest in a wider spatial context;
- the choice of the spatial granularity corresponding to the granularity of consideration of the problems we are interested in and granularity of their solutions from spatial, organizational and economic points of view (the conformity of the sizes and parameters of objects for which nature protection measures are carried out, with the amount of financing);
- the identical level of spatial granularity for interconnected processes and phenomena;
- the choice of time extent in order to represent the whole range of the phenomenon differentiation with time;
- the choice of time granularity corresponding to the operational scale of the phenomenon change with time;
- the identical level of time granularity for various interconnected processes and phenomena;
- the choice of thematic extent ensuring the consideration of key cause-and-effect aspects of the process or phenomenon under investigation;
- the choice of level of the thematic granularity that corresponds to that of the granularity of the measures to influence the process or phenomenon under consideration (for example, the localization and scale of the environment

information representation should correspond to the localization and scale of representation of nature protection measures);

- the choice of criteria for information selection and generalization, according to the policy and priorities of measures to influence the processes and phenomena;
- the methods of representation, ensuring maximal visualization, spatial differentiation of objects and corresponding as much as possible to the true localization of processes and phenomena at the chosen scale;
- the conformity and consistency of information on interconnected processes and phenomena regarding the coincidence of criteria for selection and generalization, localization, various aspects of scale, thematic extent, etc.

Conclusion

Formation and verification of the ontologies of documents, having geospatial information, within the ontological framework of cartographic modeling on the basis of the "ideal" map criteria suggested allow us to perform examination of analytical, legal and regulatory-methodological documents for their consistency, completeness and conformity to the declared purposes.

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