CONCEPTUAL MODELS FOR CARTOGRAPHIC REPRESENTATION

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INTRODUCTION

This paper was inspired by recent discussions of the possibility of a universal map language, a framework for cartographic visualization and a need for a theory of spatial (including cartographic) information in general (Moellering, 2003). In spite of a vast number of texts devoted to the semiological aspects of map language, no system has been created that would describe and explain cartographic signs in all their complexity (Lyutyj, 2002). The decisions about signs in thematic cartography today, like twenty years ago, are mostly based on sets of heuristic recommendations which do not make up a strictly logical system. The more complex the system of signs, the more difficult it becomes to apply the rules. Other than in the simplest cases, it is impossible to limit cartographic design to a single set of rules at all, hence thematic mapping can hardly be subjected to automated processing functions. Nor is there an algorithm that could be used to check the symbolization choice for correctness. In order to minimize the gap between theories and practice, we propose to concentrate on developing information models that can easily be tested for their efficiency in thematic cartography.

PROCESS-ORIENTED APPROACH TO THEMATIC MAPPING

The performance of each business function requires knowledge and that knowledge is changed or extended by the performance of the functions. Information systems are developed to manage and control the knowledge the business needs to support decision processes. If information systems within an institution are developed separately, it results in so called “island systems” such as duplicated data, duplicated efforts to create a product, inaccessible information, a variety of unintegrated technologies and other similar situations that are to be minimized. A common framework allowing the development of integrated information systems as well as choice and flexibility is known as the CASE® Method (Dodwell, 1992) or “information engineering” approach. Many models used by this method can be easily adapted for similar purposes in thematic cartography. In fact, some aspects of what we know as CASE method today, e.g., workflow diagramming and documentation, were raised to the level of cartographic theory (Ogrissek, 1987) even before the method became popular worldwide.

It is important to conceive the place of cartographic data and cartographic transcription processes within an information system of the institution first of all. Nevertheless, electronic thematic maps are complex enough to be treated as information systems themselves. The life cycle model describes the processes (the advantages of a process-centered organizational model have been proven in several studies, e.g., Hammer, 1996) that must be performed to achieve the goals of the information system in some defined order, successive or parallel, connected by the transferred data flows. Regarding the maps, it starts with the idea of doing something and comes to an end when the product is ready for use and distribution.

The essence of the system engineering approach is that the life cycle never ends but repeats itself in an unwinding spiral, whose radius demonstrates the size and complexity of the information system at a given point in time. All the data and knowledge created within the cycle are reused thereby facilitating the processes in the next cycle. However, an information system requires changes in its lifetime resulting from changes in the structure of information, the user’s environment or the requirements or expansion to system wide scope. It is highly desirable that the system could develop in this way, growing in size without losing its initial structure for as long as possible. To make this feasible, all incongruities between logical schemes inside the system must be eliminated and even then it is difficult to keep up with the changes resulting from the specifics of cartographic data (diverse and often inconsistent) and tasks (it is often difficult to separate responsibilities between them even at the highest level of detail).
In our context of cartographic visualization, assuming that the mechanism for obtaining all the necessary data is clear and reliable, the cycle can be imagined as mainly creating and maintaining a database of representations. In this paper we will try to outline the possible minimal structure of such a database in form of a semantic data model.

Figure 1 depicts the life cycles of map production where the basic stages are arranged in classical consecutive order and the general spiral life cycle model that must be applied for each of the successive stages.

The aim of the strategy study is to produce recommendations and plan for development of the product (data, map or software), ensuring that the problems of “island systems” are reduced as much as possible. The main objective of the analysis stage is to verify and expand the recommendations from the strategy stage in order to create a sound basis for design. In the design stage detailed requirements from the analysis stage are taken and carried out. Design alternatives are evaluated against user requirements until an acceptable solution is found. The processes are thereby iterative in this as in all the four stages.

The stage of visualization is the most specific in the classical model. It can be decomposed into many possibly parallel processes that can be arranged and performed in different ways within the strategy, analysis, design and production sectors of the spiral model producing deliverables as shown in Fig. 1. The processes of design deserve special attention in visualization because the most important decisions about the method of representation, signs and map layout are made in the design stage. Good design is based not only on good project management but on a good conceptual model first of all.

THE ROLE OF CONCEPTUAL MODELLING

The process of information modelling for cartographic transcription is depicted in Fig 2. It has a clearly defined place in the well-known cartographic communication model developed by L. Ratajski (Ratajski, 1973);...
however, we will not describe it in this paper but concentrate on those of its aspects related to the modelling of graphics (or other means of representation) in cartography.

Three levels of modelling must take place between the source and the physical storage of data. A conceptual model (hereinafter CM1) is the result of selection, abstraction and generalization processes applied to the part of the real world from which the data originate. It is a description made in more or less "human" terms, including objects, relationships or visual variables and can be represented at different levels of abstraction. A good model is a stable representation of real life. Logical modelling is based on a given conceptual model and results in a structure of database objects, e.g. tables in a relational database. A logical model is not required to have the same structure as a conceptual model and usually it does not. A physical model describes how data are stored in memory. All modern user interfaces are based on some conceptual model in order to make working with data more comfortable. Thus both physical and logical models normally are “hidden” from the user. The upper line in the figure depicts all three levels of modelling for geographic data. Cartographic transcription begins when there is a need to visualize these data, hence to provide a symbolic graphic interface to the data, and that in turn implies design of a specific conceptual model for map symbolism (lower line in the figure). We will call it a conceptual model for map objects (hereinafter CM2).

Fig 2. Two conceptual models in the process of cartographic transcription

Physical representations of map symbols and map objects are independent of each other. That is not the case at higher levels of abstraction. Logical models are not isomorphic but must be compatible at the database level, i.e. uniformly transformable into each other. The two conceptual models are of the greatest importance in the process of information communication and it is desirable that they be isomorphic because that is the only way to maximize the intersection of "cartographer’s reality" and "user’s reality" reproduced from the map in Ratajski’s model (Ratajski, 1973). That is the case because both models are explicitly presented for the user in form of map legend: CM2 as the graphic objects and CM1 as their textual explanations. Thus the user is prompted to think of map information in terms of both CM1 and CM2 and any little inadequacy between them becomes confusing, hindering the correct interpretation of the information, not to mention discovery of new knowledge. Moreover, it is these terms in which we get feedback from users. Unfortunately, the importance of conceptual modelling is not yet universally recognized.

We cannot expect complete isomorphism between illimitable reality and the limited realm of graphics. That is therefore relegated to the status of a theoretical ideal. In practice CM2 is in some aspects usually less and in others more than CM1. The main task of the cartographer is to ensure that at least all notions of CM1 find their representations in CM2. Considering the diversity of represented information, it is not a simple task.

1 Failing to take conceptual models into account, the building of the legend is quite often referred to as a one of the last processes of the visualization stage (Korycka-Skorupa, 2002, Schlichtmann, 2003), misleadingly suggesting that the legend is an independent part of a map. In fact, the legend as the set of prototypes of cartographic signs must be constructed even before the variable attributes of signs are chosen.

2 CM2 embracing more than CM1 is not yet the case when new knowledge is produced as a result of "explorative analysis" but rather related with emphasizing of some entities, attributes or spatial organization. Normally it is not practical to extend CM1 so as to include the notions related with human perception of signs. The influence of conceptual model “bias” and its effects on knowledge...
There are some very general requirements for this twofold conceptual model.

- ALL geographic and graphic entities with all their attributes that are of interest must be represented in the model.
- There must be a possibility to represent all the relationships between the entities.
- The model must be extensible without changing its basic structure.
- A transformation function must be defined between the two CMs at any level of detail.
- The basic rules of cartographic transcription must be obeyed: different objects represented by different signs; an object represented by the same sign in one map does not share this point of view.
- Variations of such signs; an object represented by the same sign in one map and another in another map do not share this point of view.
- The initial structure based on a hierarchical structure conveyed; general concepts represented by more abstract signs; related objects represented as related etc. (Spiess, 1970).

CONCEPTUAL MODELS OF CARTOGRAPHIC INFORMATION

There are many different ways to organize graphics and other information that is used to create a visual representation of spatial data. We will discuss only three general methods that are widely used for map graphics.

“Visual variables” approach.

There is general agreement on the graphic primitives (point, line and area objects for 2D). Variations of such primitives in size, orientation, color, and other attributes are traditionally called visual variables, introduced, classified and related to characteristics of human perception by Jacques Bertin (Bertin, 1967, 1979, 1983). After more than thirty years it is still a very popular model among cartographers worldwide. In the context of rapidly developing technologies and the opening of new possibilities for cartographic visualization, a trend to extend Bertin’s model is usually still discernible. As a result, the initial structure based on a small number of very simple graphic properties is practically lost. There were attempts to introduce alternative models of map graphics developed from the “variable’s” approach or to integrate this approach into a more universal system of map language (Ratajski, 1976, Pravda, 1977, Lyutyj, 2002), however, they were obviously more complex, less clear and finally remained almost unconsidered (although it is commonly believed in structural complexity of the graphic language).

Extended model of vector graphics

A close relationship between CM2 and interfaces of commonly used graphic design software should be expected. We do not go so far as to suggest that the delineated graphic entities should “respond to the state of art in the realm of interfaces” (Fairbairn et al., 2001) because it would not be genuinely compatible with the top-down paradigm, according to which interfaces are subordinated to conceptual models and if needed, must be adjusted to comply with them. However, modern graphic design software systems have been developed for a long time in conditions of continuous competition. They are designed obeying the principle of maximal user comfort and convey commonly accepted classification of geometric objects (described by R. Laurini and D. Thompson, 1992) and also use object models based on human perception. That is why it makes sense to compare those models to what we have to deal with in the course of the process of cartographic transcription.

Taking Adobe Illustrator® as an example we can see how graphic objects and operations are classified in its environment. We observe a coherent hierarchy of graphic objects:

- graphic primitives: points (invisible), lines, areas and text objects
- compound objects, e.g., outlined or hatched areas, graphs etc.
- groups of objects,
- layers
- page/document

There is an evident correlation between this hierarchy and toponemes (the first three classes) and assemblages of toponemes (the final three) as described by H. Schlichtmann (Schlichtmann, 2001) as structural elements of map symbolism where grouping can become a method to link up the parts of a (possibly spatially disjointed) place.

Most operations can be applied to graphic objects at any level and only some are specific to the particular level, e.g., change of color, line style and other basic attributes that are applied exclusively to the graphic primitives or change of visibility that is applied to a layer. They roughly correspond to the “visual variables” though size (scaling)
and orientation (rotation) defined by J. Bertin as primary variables fall out of this set, being among the most universal transformations. There are sets of arrangement and alignment operations applicable to several single objects.

**Semantic data models.**

Two semantic modelling techniques, entity-relationship modelling and the object-oriented approach, originate from information science and are not specifically cartographic. Entity-relationship (ER) modelling was one of the first such techniques to be developed (Chen, 1976). It has become very popular, with numerous texts introducing it for the use in all stages of a system’s design and especially for the relational database design (Date, 1986, Teorey, 1990). It is no wonder that geographic information systems, which as a rule use relational databases, are based on precisely this model. It is based on such real-world concepts as entity, attribute and the relationship between two entities. Application of this data model for cartographic transcription was described earlier (Beconyte, 2003), and will not be elaborated in the present paper.

Another choice for semantic modelling is the object-oriented paradigm (Booch, 1994) that focuses not on relationships but objects, classes, behavior and inheritance. This data-modelling technique has been developed to describe active, dynamic objects. It is more complex but also more powerful when dealing with electronic, especially interactive cartographic products that compare to software applications in complexity and process of production.

Both entity-relationship and object models are universally used for description of spatial data at the database level.

**Table 1. Main characteristics of the popular conceptual models (“−” – not present, “+/-” – weak, “+” – present, “++” - strong).**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Visual variables</th>
<th>Vector graphics</th>
<th>ER model</th>
<th>Object model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representation of spatial objects</td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Representation of classified attributes</td>
<td>+/−</td>
<td>−</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Type/domain control</td>
<td>+/- (indirect)</td>
<td>−</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Means to convey non-spatial relationships</td>
<td>+/- (indirect)</td>
<td>−</td>
<td>++</td>
<td>+/- (hierarchies, methods)</td>
</tr>
<tr>
<td>Representation of behavior</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>++</td>
</tr>
<tr>
<td>Means to reflect context</td>
<td>−</td>
<td>+/- (styles)</td>
<td>−</td>
<td>+/- (polymorphism)</td>
</tr>
<tr>
<td>Extensibility (robustness) of the model</td>
<td>+</td>
<td>−</td>
<td>++</td>
<td>++</td>
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</tbody>
</table>

The characteristics of the described models which are important for assessment of their suitability for managing information in thematic cartography are summarized in Table 1. It is obvious that semantic models, though not perfect, have much bigger potential than the other two.

A significant framework recently proposed by H. Schlichtmann blends well with the semantic models as it includes notions of abstract types and instances, hierarchies of types, attributes of different types and functions of the “expression material” (Schlichtmann, 2003).

**CRITICS OF THE “VISUAL VARIABLES” APPROACH**

It is difficult to underestimate Bertin’s contribution to cartography and graphic design. He made the first step towards a structured method of (carto)graphic transcription. What is surprising is that during the next thirty years, it was precisely Bertin’s system that was extended by different cartographers beyond its initially simple framework without attempts to modify the framework itself. Here we attempt to point out the most common mistakes (that are not necessarily due to any imperfection of Bertin’s model).

A general argument against using the term “variable” to denote the changeable properties of (carto)graphic signs is the direct meaning of this term in mathematics. A variable is an abstract entity of a particular class, or type, whose instance is unknown until the variable acquires its value. For example, values “3”, “4” or “87” can be assigned to integer variable X. That means that a variable always belongs to specific domain—integer, real or complex numbers, matrices, tables and so forth. Only one value from the corresponding domain can be assigned to it at a time.
Bertin’s “visual variables” are not separate entities, but actually dependent concepts. Indeed, it makes no sense to refer to “size” or even less, “orientation” without some object of which they are attributes. However, in this model variables are treated as something unrelated to any objects, thus making discussions about “right choice” of them quite abstract.

The “visual variables” have no types either. In fact, they should be treated as data types/domains themselves. For example a variable Color which is from domain (“Red”, “Yellow”, “Green”), could be assigned value “Red” from this domain; a variable RGB Color which is from RGB domain, could be assigned value (255,255,0) from this domain. No type/domain assignment leads to unnecessary investigations into levels of measurement of all possible kinds of “variables” or even ungrounded conclusions such as “using hue for a non-nominally scaled attribute is a poor symbolization choice” (Robinson et al., 1995). In fact, hue is quantitatively measured by degrees on a color wheel and in case of relief changes from green through yellow to red often help to easily recognize prevailing type of relief (lowlands, highlands and mountains correspondingly). But in any case, a sound choice of variables does not only depend on type matching, but also on the kind of object to which it is applied (e.g. background color of a polygon, color of its contour line or the color of lettering).

The main consequences of neglecting objects and type control are as follows.

1. The model does not include all possible types of cartographic signs. In fact, only very simple iconic signs can be described in terms of “visual variables” without difficulty. Some categories, like shape, size or orientation, do not apply for signs of areal or line dimensionality which represent geographic features. They are, however, fully applicable to other graphic objects of the same class, e.g., pie charts or arrows.

2. All “visual variables” are polymorphic without any possibility for control, e.g., “size” might refer to radius, height, length, thickness, volume, radius of bounding circle, structure [width, height] etc. The same names of different variables imply their inter-comparability, yet it makes no sense to compare values from different logical domains: even though a thickness of a line and a height of a bar are measured in the same units (e.g., points), comparing one to another is meaningless.

3. It is not possible to show how different variables are employed for different purposes, e.g., emphasis or clarification (Schlichtmann, 2003).

4. Map designers have to take into account the fact that a single object can not only have several representations that must change with the scale of the map, but sometimes an abstract object (e.g., a town) becomes a set of its components (buildings, streets, squares) when the scale is large enough. There is no place for such an event in the model.

Although the importance of visual perception of relationships rather than of single objects is stressed in Bertin’s study, the relationships are limited to simple hierarchies or sequences. It is obviously not enough considering the fact that more and more complex phenomena are to be represented in maps.

And finally, variations of graphic characteristics are not only dependent on the objects but also invariably take place in some context and must be investigated within that context, as long as pragmatic aspects of cartographic communication are taken into account. Unfortunately, pragmatics is still a weak point in modern cartography as was pointed out by T. Zarycki (Zarycki, 2001).

**Comments on particular variables.**

Besides location, six primary “visual variables” (size, orientation, shape, hue, brightness and grain) were defined by J. Bertin, and later on the set was extended and systematized (Robinson et al., 1995), with six counting as primary (size, orientation, shape, and color as value, hue and chroma) and three as secondary (pattern as arrangement, texture and orientation).

**Location.** The location attribute of a cartographic sign is usually determined by geographic coordinates of the represented object, however, position can vary if location is specified as a reference to some geographic object, for instance, an icon sign can be placed on either side of a city dot marker or aligned with other signs in a group.

**Shape.** The notion of shape is so closely related to the object itself, that naturally a question arises as to whether two objects of the same shape are really different objects, and if so, whether there are identical objects in a map at all. In fact, an object of a different shape is perceived as another object rather than as the same object with a different shape property. There could be an argument on whether non-uniform scaling produces a different shape or not. What is really variable about shape can be graphic resolution, fuzziness (both introduced by A. MacEachren as separate variables, MacEachren, 1992) and style of drawing (rounded corners or other artistic stylizations) as shown in Fig. 3.
Orientation. There are two ways to organize signs with different orientation:

a) isolated signs far away from each other in the map,

b) visually separable groups of signs with different orientation.

In the first case there is a probability that the map reader will not notice this difference and perceive them as the same sign. In the second, if objects are visually expressive, an opposite orientation of objects within a group often implies variously moving directions; if they are abstract geometric shapes or patterns, they are normally perceived as different shapes (Fig. 4). Considering that, it is difficult to understand why such importance was given to this variable.

Size. The only result of treating size as an independent variable without any implications about its measurement can be a naive recommendation like “The larger a sign, the more important it is thought to be” (Robinson et al., 1995). Some aspects related to size are depicted in Fig. 4.

Color. Color as we perceive it is made up of three components: hue, which is the main one, brightness/intensity and chroma/saturation. Either of them can be employed to represent some characteristics of the represented object, however, none of them exists can exist without the other two. Thus color is a structure of at least three components (maybe four if not the “humane” HSB but, for instance, the CMYK model is used) and different colors differ in values of at least one of their components. In fact color is closest to a separate, though abstract entity. We can imagine it as a painted rectangle or an electromagnetic wave.
Texture (pattern). It is considered to be a secondary variable, most likely because it is so difficult to provide a formal description of it. Actually, in black-and-white images patterns completely replace colors with all three of their components (shape of the repeated element as hue; size of the repeated element as brightness; density as saturation), all preserving the levels of measurement (Fig. 5).

The problem is that it is quite difficult to tell background patterns apart from compound shapes (Fig. 4). It is impossible to formally define the difference between a single pattern and several patterns laid over each other. Finally, it is obvious that a pattern can have an infinite number of diverse graphic properties notwithstanding that infinity is not something we want to deal with making use of any semantic model. Perhaps the most natural way to describe pattern would be a recursively defined structure: systematically arranged elementary objects or patterns.

Sets of haptic, sonic, temporal and other "variables" were added by numerous researchers (DiBiase, Vasconcellos, Krygier) mainly in the last decade of the century (Visualization in Modern Cartography, 1994) and some of different types have yet to be added as they become practical thanks to new technologies. As long as their usage is clear, new variables/properties can be discussed within Bertin's framework or without any framework at all. It becomes more problematic when some spatial relationships, such as arrangement or density (MacEachren, 1995) are misinterpreted as types of Bertin's variables which are attributes, thus mixing up the very basic philosophic categories and rendering the whole model even more inconsistent. The same kind of mistake is made by introducing characteristics of dynamic behavior in the set. In the latter case, there are no limits for complexity raising questions, if, e.g., temporal variation of color in brightness is just one more variable? Is variation in both color and size a variable of the same type or a variable of some other type? Is the frequency of these variations another variable? Are this frequency and the frequency of a sound two different variables? And finally, can we call a model, in which an unlimited number of types occur, a structured approach at all?

**Fig. 5. Replacement of color components by patterns**

Bertin’s model has not become obsolete or too limited simply as a consequence of the new technologies. Concepts of relationship, change, behavior, sound or touch have always existed as universal and do not depend on technology any more than technology provides better tools to employ them in cartography.

**PROPOSED OUTLINE OF A MODEL OF MAP GRAPHICS**

It was not a goal of this paper to introduce some elaborated model in which all aspects of cartographic signs would be given appropriate formalism. That does not yet exist. We are merely trying to demonstrate the need for a new model and provide a first tentative framework for its development. Other paradigms can be applied as long as the model is equally practical for cartographers, information scientists and geographers. Considering the growing importance of the map user we would argue that it must in the first instance be convenient for that user.
CM1 can be a simple object model where every object has a name as a non-obligatory attribute. Objects in CM2 are pairs of graphic signs (point-, line- or area-emphasized) with lettering as non-obligatory component. A graphic sign is an object designed to represent instances of a geographic entity in the map model or an abstract entity in a map’s legend. It can be assigned different methods of behavior (playing sound or video are only two examples of such methods; complex animation by contrast comprises a set of methods). Methods and attributes should never be confused, e.g., the PlaySound method which is the same for different objects can use some attribute information which is a particular sound record, but that is different for different objects. To avoid confusion with the pure object model, we propose a dual object model in which CM2 objects are the “sign-lettering” dyads.

The shape of a graphic object is determined either by geographic coordinates or is that which we identify with the cartographic sign itself. Graphic objects are either primitives (lines or areas) or compound signs which are combinations of the primitives. Shapes of particular components of compound signs can represent super types of the represented object in some hierarchy. Consistency of identifying objects with shapes is fully preserved in this case, for objects inherit elements of their shape from their “parents” (the variable attributes of lettering can represent super types as well). Orientation, if used for semantic binding at all, should represent the concept of “direction” as it is perceived in the real world.

Attributes and methods of CM2 objects are of two types. One set of attributes comprises pre-assigned values that do not change in concrete instances. Other attributes must be allowed to vary in values and assigned values for visual representation of an instance of geographic entity that depends on the values of the corresponding attributes of that entity. A monosemantic correspondence between the sets of variable attributes in both models must be preserved. During this process all the domains must be checked for compatibility taking into account the general rules of cartographic transcription and the purpose of visualization. This is a much more flexible path to proper symbolization. Polymorphism can transpire in so far as different properties or methods can have the same name; however, in this case, objects are responsible for correctness of operations and type control.

The number of fixed attributes exhibits the graphic complexity of a sign which is not semantically bound. It allows the cartographer to decide for or against this extra complexity in different contexts. Fixed attribute-value pairs together with shapes of signs also make up the design style of the map.

The structure of compound objects can be not only designed for better symbolization but can also imitate a real structure (a most natural example is a pie or bar chart showing population by age or nationality).

Behavior methods of cartographic objects can be used for three main purposes:

a) as interfaces to object data providing additional information that is not normally visible (audible, tangible etc.) or linking to other objects — this is the main usage of interaction methods;

b) as imitations or symbols of real behavior of the represented object — changing to representations with scale in interactive maps; moving, varying in size or other temporal behavior in animated maps;

c) as a method of emphasis — periodic variations of some attributes in order to attract attention (like blinking) — quite derived for permanent emphasis but useful when some event related to the object occurs.

A (visual) variable according to the logics of this model is an unknown cartographic sign of particular type, e.g., TownIcon_X can be assigned a value of “Capital_World_5M” which in our case is a dot marker or “Capital_Lithuania_50K” which is a shaded area. More strictly, cartographic signs must be treated as vectors in n-dimensional space where n is the number of all attributes. All possible values of vectors with the same set of m variable attributes form a cluster in that space and different operations are possible with such clusters. Thus it becomes possible to define graphic equivalents for single “words” and “phrases” and the idea of creating some universal “map algebra”/map language seems more practical. The number of variable attributes (so called attribute depth) can be measured as the potential information load (or semantic complexity) of a sign. It also becomes possible to compare all the values of such attributes of two signs and to measure the difference between them. It is a kind of semantic “distance” at least as a vector in multidimensional space, and in some cases as a single numeric value.

It must be said that although this approach is not particularly compatible with the field data models (e.g., DEM) it can still be useful because the data set of a physically continuous field is never actually continuous. It is rather...
CONCLUSIONS

In summary, all the models used during the life cycle of a map, atlas or an entire cartographic production company must be linked up to each other and intrinsically coherent in order to improve the efficiency of performance and quality of the expected result. Special attention must be paid to the stages of analysis and design in the aforementioned life cycle and particularly to conceptual modelling. A well-structured approach in these stages is essential for a sound cartographic transcription which eventually results in improved usability of the map. Unfortunately, information concerning the methodology of representation is often treated separately from the information to be represented.

In pursuit of efficiency the conceptual model of map graphics must be designed as a framework, as close as possible, if not completely isomorphic to the model of information to be rendered visually. The commonly used system of “visual variables” does not comply with this requirement; however, Other simple and elegant modelling techniques can be applied in order to develop such a framework, encompassing the “visual variables” as well.

An object model is taken as a basis for the proposed twofold conceptual model in which the representation model is linked and subordinated to that of the spatial data. An entity-relationship model is more suitable for static representations, while the actual object model is perfect for dynamic, interactive images and multimedia attributes. Irrespective of which of the two techniques is actually used, the main features in outline are as follows.

- **The cartographic** sign as a representation of a spatial entity with lettering as a representation of its attribute(s) from a textual domain.
- There are two sets of attributes for each primitive or compound graphic object: fixed and variable. Variable attributes are the designer’s choice as long as their domains match the number and domains of the attributes of the represented spatial entity. They roughly correspond to the “visual variables”; however, some of the initial “variables” are used for different purposes.
- Similarly the fixed attributes can be assigned different representation functions.
- Type control is explicit.
- The concept of inheritance is employed to convey hierarchies.

This model can easily be mapped onto the structure of a relational or object database of representations. Database management concepts, such as consistency, normalization and so forth can be considered in terms of the model.

The more limited object here is to provide a framework that can serve as a basis for identifying narrowly defined categories.

REFERENCES

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