Concepts of Map Language for GIS

Branislav Nižnanský[1]

[1]Katedra geografie, Pedagogická fakulta, Katolícka univerzita, Námestie A. Hlinku 1,
034 01, Ružomberok, Slovenská republika
niznansky@fedu.ku.sk

Abstrakt. Koncepty mapového jazyka pre GIS. Základný prvok mapového jazyka – mapový znak je definovaný a opísaný pomocou trojice atribútov. Atribúty mapového znaku a hlavné koncepty využívané pre opis atribútov mapového znaku tvoria bázu konceptuálneho a logického modelu pre GIS založeného na mapovom jazyku, a tvoria aj jadro postupu konceptuálnej analýzy máp. Konceptuálna analýza 570 tematických vrstiev odlíšených v 436 mapách Atlasu krajiny SR tvorí empirickú základňu diskusie o konceptuálnom a logickom dátovom modeli založenom na kartografickom poznaní. Využitie konceptov získaných konceptuálnou analýzou atribútov mapového znaku je možným východiskom budovania kartografických vzorov v dátových štruktúrach GIS. Základom využitia uvedenej konceptuálnej analýzy pre GIS je chápanie mapového znaku z hľadiska semiotiky ako množiny dvojíc tých istých typov charakteristík: charakteristík položiek dát (v GIS) a charakteristík grafických prostriedkov použitých na tvorbu systému mapových znakov. Mapový znak (jednoduchý alebo zložený) je chápaný ako obraz (portrayal) priradený kartografickému vzoru (cartographic feature). Pod kartografickým vzorom je chápaná trojica: identifikačné dáta, priestorové dáta, nepriestorové dáta. Mapový znak v zmysle obraz kartografického vzoru je chápaný ako trojica: identifikačná charakteristika grafickej jednotky (prípadne aj alfanumerický identifikátor), sémantická referencia grafickej jednotky na matematický základ mapy (priestorové dáta z kartografického vzoru), sémantická referencia grafickej jednotky na charakteristiky nepriestorových dát z kartografického vzoru. Výsledkom analýzy je tabuľka funkcie označovania, ktorá je podkladom pre ontológiu GIS z pohľadu tematickej kartografie.

Kľúčové slová: mapový znak, grafická jednotka, areál grafickej jednotky, význam, sémantická referencia, umiestnenie v mape, poloha, pôdorys, kartografický vzor, obraz kartografického vzoru

Keywords: map sign, graphic unit, graphic unit area, meaning, semantic reference, location in the map, position, plan, cartographic feature, portrayal of cartographic feature

1 Introduction

The map language theory [8, 9, 10, 11, 13, 15] is founded on the analogy between language and map expression. We can see the both as a system of base elements (words, signs) and set of rules for their use in communication process. Base element of the map language –map sign is defined and characterized by his three components [4, 8, 13]. The possible definition is: “Map sign is a graphic unit with some content (meaning) and with a position in a map [15]”. *Graphic unit*, *spatial and non-spatial content* is a base for set of concepts to create possible conceptual and logical data model founded on the cartography (cartographic knowledge-based system).

We can put the theory more exactly by conceptual analysis. Verifying of the theory is based on the finding the three map sign attributes in the 570 thematic layers distinguished in the 436 maps of the Landscape Atlas of The Slovak Republic (Atlas krajiny SR [1]).

Concepts obtained and verified in the process of the analysis can be used to discuss conceptual and logical data model on geographical information. The main idea of the use of this conceptual analysis for GIS is to represent the semantics of the application domain model as a set of couple. The couple is defined by the same type of data characteristics: [cartographic feature data characteristic, cartographic portrayal graphic mean characteristic].

Map sign (simple or composite) is conceptualized as a portrayal of cartographical feature. Conceptual model of the cartographical feature is a triple: [identifier data, spatial data, non-spatial data]. Conceptual model of the portrayal – the map sign (simple or composite) is a triple: [identifier attributes of the graphic unit (+ alphanumeric identifier sometimes), semantic reference of the graphic unit to the spatial data, semantic reference of the graphic unit to the non-spatial data].

We show and describe results of the analysis and the base concepts for GIS derived from cartographic application domain model (tab 2).

2 Computational models and GIS

Conceptual, logical and physical database design, semantic model of the data and conceptual data schema are ones from the more base concepts to expression cooperation between specialists, analyst, designer and potential users which take part in variable activities connected with problem of GIS.
For data-intensive applications the area of computing technology that leads from problem specification to system implementation is database design, further subdivided into conceptual, logical and physical database design stages. The purpose of database design being is to organize data for effective processing, the stage of **logical database design** focuses in transforming a **semantic model** of the data (which is an expressively rich and user understandable one, by Vossen 1991, pp. 194) into a formal record-oriented, system independent, yet system implementable, description. For this purpose, we need a logical data model and rules for transforming the **conceptual data schema** into the logical data model. Such rules are partially algorithmic and partially heuristic, reflecting the fact that some of the transformations are mechanical, while others (such as determining the layers for spatial systems) constitute non-automatable design decisions [3].
By Worboys and Duckham [19] the choice of appropriate data model can be the critical factor for the success of failure of an information system. In fact, the data model is the key to the database idea. Data models function at all levels of the information system. The process of developing a database, or indeed any information system, is essentially a process of model building. At the highest level is the **application domain model**, which describes the core requirements of users in a particular application domain, based on an initial study. At the next level, the **conceptual computational model** provides a means of communication between the user and the system that is independent of the details of the implementation. The process of developing a conceptual computational model focuses on questions of what the system will do, termed system analysis. The **logical computational model** is tailored to a particular type of implementation. The process of developing a logical computational model focuses on questions of how the system will implement the conceptual computational model, termed system design. Finally the low-level **physical computational model** is the result of a process of programming and system implementation. It describes the actual software and hardware application, including how data is processed and organized on a particular type of machine.
A **conceptual data model** is a model of the proposed database system that is independent of any implementation details. A conceptual model must express the structure of the information in the system: that is the types of data, and their interrelationships. Such structural properties are often termed *static,* but the system will also have a *dynamic* component related to its behavior in operation. For example, the allowable transactions with the system shape its dynamics properties. A good conceptual data model can act as an efficient means of communication between the analyst, designer and potential users. This will aid the design and implementation of the system. Further, when the system is eventually implemented, the conceptual data model provides a basic reference for users who need to understand the structure of the data in the system. In summary, conceptual models:
1. Provide a framework that allows the expression of the structure of the system in way that is clear and easy to communicate to a non-specialist.
2. Contain sufficient modeling constructs so that the complexity of the system may be captured as completely as possible.
3. Have the capability for translation into implementation-dependent models (i.e., logical and physical models), so that the system may be designed and built.

3 The map language theory about the three map sign attributes

Although not always explicitly viewed in this way, geographic and cartographic applications are usually part of information systems, such as decision support, cartographical or geographical visualization or spatial oriented management system. We can ask how cartographical issues affect the design of any information system, the development of which is a discipline by itself, not only because of the far-reaching implications of an information system but also because of the complexity involved in constructing one. Map language as part of cartographical theory can be used as base of the cartographical issues. Map language (Pravda in: [14]) can be defined at the present moment as a system of map signs and rules of their use. Knowledge of this system makes it possible for anyone (who wishes so, i. e. not only cartographer) to express his thoughts on space in a form of map (in a cartographic way) and/or to read and understand the map contents, denoted by these signs. There are three properties of the cartographic sign in the map language conception which are defined as the cartographic triad (Pravda, 1987): form (sign vehicle), content (meaning), and localization (position). Base concepts for GIS data visualization are constructed by three properties. The term: form (sign vehicles) by Pravda [14] we describe as a **graphic unit** (by Bertin [2] and Nižnanský [11]). The terms: content (meaning), and localization (position) we describe as a **non-spatial** and a **spatial content**. The presented part of map language theory [11] is transformed and reduced by author.

3.1 Graphic unit and graphic means

Graphic units (GU) are built from one or more graphic elements (simple graphic unit). The simple graphic unit is described as a set of graphic variable values. Graphic variables (see fig 4 in appendix) are used in static or dynamic mode. In static mode graphic variable value is an attribute of graphic unit (shape, size, orientation, color type, color intensity, pattern type and pattern intensity). In dynamic mode we express change of graphic variable value by five geometric graphic operations and by five graphic operations with color or pattern (tab 1) – unary graphic operations. If we have some base set of graphic elements then we can construct open graphic alphabet using rules based on the graphic operations.

Table 1. Relation "graphic variable – unary graphic operation"

Semantic reference	**Geometric unary graphic operations**		**Unary graphic operation with color and pattern**	
Level of reality description	**Operation**	**Change of graphic variable value**	**Operation**	**Change of graphic variable value**
quality (Q) or distinguish level	Sv	Shape variation	Ct	Color type (e.g hue)
	S	Orientation – by symmetry	Pt	Pattern type
quantity (M) or comparison level	R	Orientation – by rotation	Cint	Color intensity (e.g light, saturation)
	H Mv	Greatness–by homotetion – by one dimension only (measure variation)	Ped Pes	Pattern intensity – by density – by dimension of pattern graphic element

Explanation: C(P)t – color (pattern) type change, Cint – color (pattern) intensity change, Ped(s) – pattern element density (size) change.

The composite graphic unit can be described as a set of simple graphic units. We use three main topology attributes of simple graphic unit: border, inside and outside (see fig. 1) to describe composite graphic unit by topology relations (static description) or as outcome of topology operations (dynamic description).

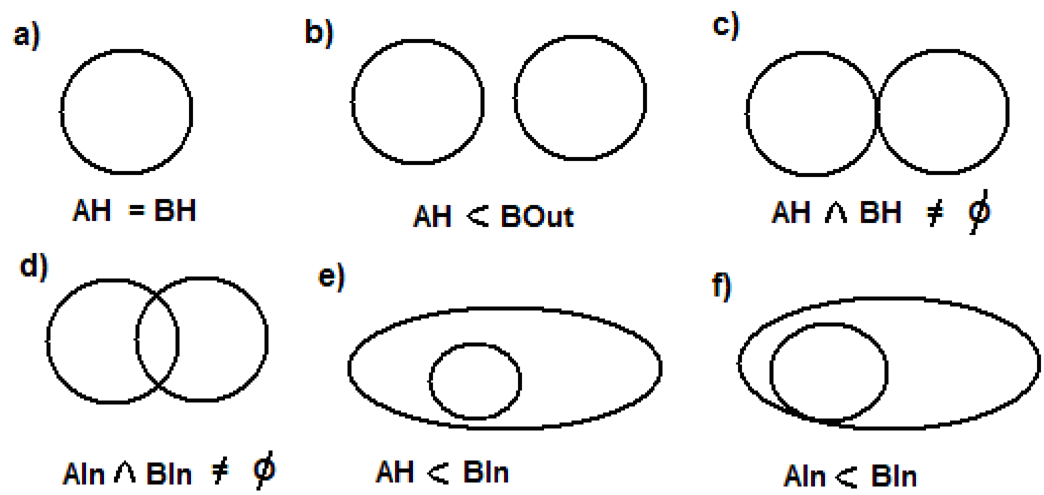

Fig. 1. The example of a set-oriented and/or topological base of the composite graphic units. The graphic relation/operation. Topology of GU: AH, BH – border of A or B, AIn, BIn – inside of A or B, AOut, Bout – outside of A or B.

In the catalog of spatial operations [19, p. 158] we can find more operation as it is mentioned here. For our analysis we used five types of binary graphic operations derived from map language theory (Pravda, 1990 a 1997, Nižnanský 2002, 2004, 2006a, 2006b): R1 –aggregation (or aggregation with ordering), R2 – connection, R3 – connection/dividing (by common border), R4 – dissociation, R5… – overlaps, covers or put inside.

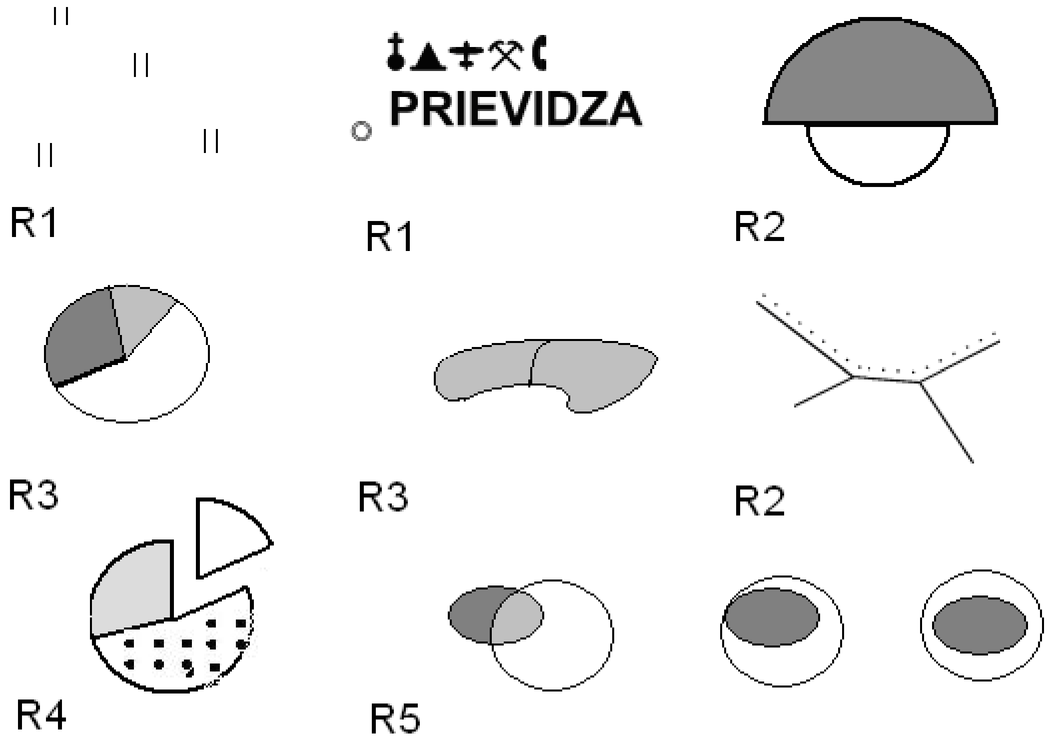

Fig. 2. Binary graphic operation derived from map language theory: R1 .–aggregation and aggregation with ordering, R2 – connection figural and linear referenced graphic units, R3 – connection/dividing (by common border) figural and area referenced graphic units, R4 – dissociation, R5 – overlaps, covers or put inside.

The static and dynamic description of the graphic variable and topology of a composite graphic unit is a base for graphic means set creation. The set of graphic operation {Sv, R, S, H, Mv, Ct, Pt, Cint, Pes, Ped, R1-R5…}and base set of graphic elements (graphic element is a set of graphic variable value defined in the graphic space) is a way to formally describe the graphic component of the map language code.

3.2 Spatial and non-spatial content (meaning) of the map sign

The syntax analysis of map language is the main problem for using the map language theory to create; conceptual model based on the three attributes of a map sign. Primary it is a problem to analyze attribute content (meaning) for good formalization. Hence in analysis of syntax we will not use meaning of a map sign but possibility of meaning aspect (meaning or content potential) – in this theory named **semantic reference.** We define two attributes of map sign (spatial and non-spatial content) as a triple based on the three components of set C.
Content (C) of map sign is a set:

$$C = \{Fd, Sr, Ca\}$$

Where:
Fd is a designation function (possible representation of designation function see at tab. 2),
Sr is a semantic reference of a graphic mean,
Ca is a content attribute or item identifier of the data.
Designation function is a set of twos [Sr, Ca] determined by rules and principles of designation. Designation function is defined as a status in T_1 (in a time moment or interval). We can use two or more designation function to model spatio-temporal objects.

We distinguish two type of the map sign content (meaning): spatial and non-spatial.
Sr is a spatial semantic reference of a graphic mean and Ca is a spatial data type of a cartographical feature in the spatial content, Sr is a non-spatial semantic reference of a graphic mean and Ca is a non-spatial data type characteristic of a cartographical feature in the non-spatial content.
Conceptual model of the cartographical feature is a triple: [identifier data, spatial data, non-spatial data]. The objective to define cartographical feature as a data structure pragmatically chosen from geographic data is to visualize some representation of the geographical reality.

Spatial semantic reference of the graphic unit. Position in the map is important attribute of the map sign. Position of a map sign in the map is relation: map sign – map mathematic base expressed by:

- relation: map sign – scale of map (based on GU topology semantic reference)
- absolute position of the map sign (based on GU geometry semantic reference)
- relative position of the map sign (based on Graphic operation semantic reference)

Relation: map sign – scale of map (based on GU topology reference) is a tool to assign one of three classes to a graphic unit: **F** – figural referenced, **L** – linear referenced and **A** – area referenced.
Note: We can use scale of map in the case of linear sign to detect the length of the object expressed by the sign and in the case of area sign to detect plan of the object expressed by the sign.
Absolute position of the map sign is the scale defined by the two extreme positions: first is topographic (**Top**) and second is schematic (**Schem**). Topographic part of this scale is determined by the preciseness of map sign position.
Note: We can detect coordinates of the object expressed by the map sign on a preciseness level. On the other side of scale is schematic localization of the map sign. If we use schematic localization we leave preciseness and we use other graphic tools for map expression (e. g. graphic harmonization, anamorphosis, …) with the maximal keeping of the topological and direction relation.
We can describe a *relative position of the map sign* in the system of map signs. Relative position of a map sign and its parts is described by the topological (Fig 1, Fig 2, Tab 2) and direction relations between geometric models of map signs or between graphic units (elements) on the three levels:

- graphic structure of a map sign (S - simple or C - composite GU)
- composition GU to express object as a aggregated set of map signs
- map expression method (map layer of graphic units)

Non-spatial semantic reference of the graphic unit. Semantic reference (Sr) is a set of meaning potential attributes named by the term: **Q** - qualitative, **M** - quantitative, **S** - simple, **C** - composite, **F** - figural, **L** - linear, **A** - area, **Top** - topographic, **Schem** – schematic. Objects expressed by the map signs can have the same attributes (Q, M, S, C….). Sr is a subset of a set attribute characteristics AC = {Q, M, S, C, F, L, A, Top, Top/Schem, Schem, R1, R2, R3, R4, R5, …} used to describe a graphic unit as a set of semantic referenced attributes, Ca is a subset of AC set too. But elements of AC describes the data of the object expressed by a map sign.

3.3 Conclusion of the theory – proposal of the research study

Map sign (simple or composite) is conceptualized as a portrayal of cartographical feature.
Conceptual model of the cartographical feature is a triple:
[identifier data, spatial data, non-spatial data].
Conceptual model of the portrayal – the map sign (simple or composite) is a triple:
[identifier attribute of the graphic unit (+ alphanumeric identifier sometimes),
semantic reference of the graphic unit to the spatial data,
semantic reference of the graphic unit to the non-spatial data].
All maps can be constructed in the three phases. We use the three levels of the element combination mentioned above.

1. In the first level we construct a map sign as a graphic unit with both: a spatial semantic reference and a non-spatial semantic reference of GU.
2. In the second level we construct GU based map layer (with chosen graphic means).
3. In the third level we construct map as a system of map layers and system of map sign.

Map sign level base elements are:

- set of graphic elements (graphic element is defined as a set of graphic variable value),

- graphic unit space (simple and composite graphic units and GU compositions),
- set of graphic operations {Sv, R, S, H, Mv, Ct, Pt, Cint, Pes, Ped, R1-R5…},
- rules for open graphic code construction based on the graphic means,
- geometric and topology potential of GU,
- spatial and non-spatial semantic reference of graphic unit.

Result and aim of map sign level base elements use is: set of graphic units well described for map design as base graphic data set.

Map layer level base elements are:

- F, L, A reference and combination of this three classes,
- alternative semantic reference S or C (Q or M) used in symbolization process
- position in Top-Schem scale for each map sign (or GU in the case of a GU composition).

Result and aim of map layer level base elements use is set of all map layer types based on the combination of the map sign semantic reference types:

FSQ	LSQ	ASQ	FLSQ	FASQ	LASQ	FLASQ
FSM	LSM	ASM	FLSM	FASM	LASM	FLASM
FCQ	LCQ	ACQ	FLCQ	FACQ	LACQ	FLACQ
FCM	LCM	ACM	FLCM	FACM	LACM	FLACM

To verify the theory (e. g see tab 3 – 4) we use base elements mentioned above as a concepts for analysis of the thematic maps of the Landscape Atlas of The Slovak Republic (Atlas krajiny SR [1]). The objective of the analysis is to find answer to the question: Is it possible to use the base elements and rules distinguished and described above to create conceptual and logical model for GIS data visualization based on the cartographical point of view?

Advances of the theory verification:

1. First approach and analyze
    - 570 thematic layers distinguished in the 436 maps
    - thematic map layer identification (number of chapter, number of map, scale, number of layer)
    - topographical background (waters, borders, settlements, relief, railways ….)
    - topology (spatial) reference of GU: A, A(L), AL, AF(L), AF, (A)FL, L, LF, L(A), F, F(L), F(A)
    - geometry (spatial) reference – Schem (Boolean)
    - graphic operation (spatial) reference – composition, aggregation, connection, dividing, n- overlaps, ring barking
    - non-spatial data characteristics -- Q, Qhierarchy, Mint, Mext (rel, abs), S, C, Bipolar, Time
    - non-spatial graphic variable reference – Ct, Pt, Pt(C), C+P, Cint, Pint, Shape, Size, Orientation

Note: Explanation of the shortcuts or letters see above.

2. Second approach and analyze
    - thematic map layer identification (number of chapter, number of map, scale, number of layer), analysis of a difference between number of layer in the first and second approaches
    - topology (spatial) reference of GU (they are mentioned only different types in comparison with first approaches) (A)L, A(Lp), A(Lp)F, (Alp)F, (Alp)F-Rg, A(Lp)L, A-Rg, A>F, AA, AAL, ALF, F(A)L, FF, F-Rg, FF(L)
    - non-spatial data characteristics: Simple/Qualitative: B, N, Simple/Quantitative: M, O, Ot, A, Ia, Ir, Composite/Qualitative: BtB, NB, NN…, Composite/Quatitative: BIa, OB, ON.., OO.., OIa, OA, OpIa, OIr, OIrTB, NA, NAB, NIa, NIr, AA.., Air, IaIr,

Note: B – binary, N – nominal, O – ordinal, A – absolute values, Ia – interval of absolute values, Ir – interval of relative values.

- graphic means analysis (graphic variables and graphic operations), the most usable types, one graphic variable only: Fint - 103, Ft - 59, Ft(Int) – 16, Pt – 17, Pint – 5, Size – 9, Shape – 11, Color and pattern in combination – 106, layers with topology (binary) graphic operation - 133
- type and number of alphanumeric identifier in the thematic layer, name – 33, number – 24, class – 20, value – 46, time value – 2, combination of identifier type – 4

3. Comparison and simplification
    - all language means and items of data types was analyzed for proposal of designation function table (tab 2)
    - topology (spatial) reference of GU was concentrated to the table of frequency (appendix of the article, tab 3a, b, 4a, b)
4. Proposal to describe designation function as a set of couples using structured concepts (cartographical feature and his portrayal)
    - proposal of the concepts for cartographical feature, their structure and data types and proposal of the concepts for portrayal of cartographical feature, their structure and data types to create legend of the table for designation function description (tab. 2)
    - field of designation function table marked by x if a couple [Sr, Ca] really exists in the analyzed thematic map layers

4 Designation function table

In the table 2 which describes designation function we can find three sets of information description creating the couple [Sr, Ca] found in 570 thematic layers distinguished in 436 maps of the Ladscape Atlas of Slovak Republic: **Feature**, **Portrayal** and indicator of **Couple (**set of relation between Feature items and Portrayal items).

Set **Feature** (description of the data structure of the cartographic feature) is composed of three main components: Identifier, Spatial data type, Non-spatial data characteristic.

Identifier was distinguished in the thematic layers as an important mean in the second approach and analysis. It was distinguished in five types of identifiers: Name, Type (class or name of type), Code (number, letter, shortcut or acronym), Value (number as status value or time value). Most objects are identified implicitly (i) by attributes of the GU (by Attributes).

Spatial data type of cartographical feature can be described by two levels (simple, composite) and by two tools: topology and Euclidean space. Simple object plan types (based on the topology) are Node, Line, Area and Set of Nodes. Composite object plan types (based on the topology) are Tree, Star, Net and Polygonal divided Area (Fig 3)

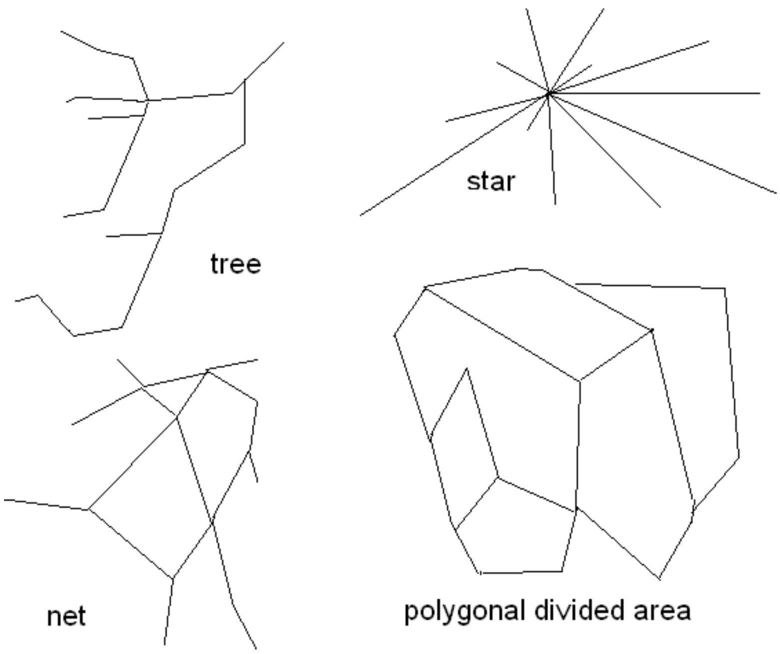

Fig. 3. Composite object plan types based on the topology referenced to the spatial data type of cartographical feature.

Non-spatial data type (data characteristic) in the cartographic feature can be classed to the three classes: Qualitative (Q) characteristic – Binary (B) or Nominal (N), quantitative (M as much) characteristic – Absolute value (A), Intervals of absolute values (Ia), Relative (R-ratio) and Intervals of relative values (Ir). The third group of non-spatial data characteristic is related to the non-spatial relation in the cartographic feature as a hierarchy, set-oriented relation as member of, subset, union, difference …

Set **Portrayal** (description of the data structure of the portrayal of cartographic feature or graphic data structure) composes of three main component: Identification by, Spatial semantic reference and Non-spatial reference of GU.

The objects are identified in the map layers by the attributes of used graphic unit (in the circa 500 thematic layers) and alphanumeric identifier (T – as a text) can be sometimes used (in the 129 thematic layers only). Identification of the geographical object (type, value or attributes) is possible implicitly by: Simple GU, Composite GU, GU Composition and Layer of GU and explicitly by: Simple GU + T (aggregated with text), Composite GU + T and in the GU composition + T.

Spatial semantic reference of the graphic unit is possible distinguished as a set of three types of references: reference to the GU topology – F (figural), L (linear) or A (area), reference of the GU geometry – Top (topographic), Top/Schem and Schem (schematic) coupling to the points of math base of the map. The third type of spatial semantic reference of the GU is reference to the Graphic Operation (R1 – R5).

Non-spatial semantic reference of the graphic unit is based on the graphic variable in the static status: Graphic variable – Shape, Size, Orientation, Color type, Color intensity, Pattern type and Pattern intensity and on the graphic variable in the dynamic status: Geometric Graphic Operations, Graphic Operations with Color and Pattern and Topological Graphic Operation.

In the field of table 2 is described coupling between feature data type and portrayal graphic data reference by indicator of **Couple (**set of relation between Feature items and Portrayal items). Symbol x shows possible relation (coupling) found in the analyzed map layers, symbol i shows possible relation derived implicitly.

5 Conclusion

In the article is presented the next step to finding theoretic and cartographic oriented base of conceptual model of map editor. In the process of the analysis of the 570 thematic layers distinguished in the 436 maps of the Landscape Atlas of The Slovak Republic (Atlas krajiny SR) we revise and correct many claims and constructions of the map language theory. The frequency analysis of the appearance of the map language means bringing new point of view to the concept creation and definition process (chapter 3.3 point 2 in the part Advances of the theory verification and table 3 a, b and 4 a, b in the appendix of article)

A graphic mean (graphic variable, graphic operation) can be used for designation of identifier, spatial and non-spatial data item. In the process of the first approach and analysis we must correct and append the language elements primarily derived from the map language theory (chapter 3.1 and 3.2). We must realize change in the approach (second approach) and correct and append the language elements primarily derived from the map language theory in the process of the second approach too.

All thematic layers possible to describe by theoretic language means (minor changes were realized by extension and correction of language elements in the process). More than 90 percent of researched and analyzed means are the same in the both approaches. This means that the map layers description is possible to use in more than 95 percent.

The table of designation function and conclusion of this article are the base for the analytic device, which is a tool for definition of default and possible coupling between geographical data used for cartographical features and graphical data used for portrayal of cartographical feature description. Thus we have base for GIS ontology building founded on cartography domain.

In the next (third) approach we must analyze position of unary graphic operation for spatial references and binary graphic operation for non-spatial references. We need to use the experience from the designation function table creation e. g that static graphic means are used for map layer distinguishing and dynamic graphic means are used for map sign in the layer distinguishing.

Table 2. Designation function in the Landscape Atlas of SR as a set of couple data type [GI ordered as a cartographical feature; graphic and semantic ref. used to portrayal map signs or map layers] (see at next page).

Portrayal \ Feature			Identifier					Spatial data type of cartographical feature																Non-spatial data characteristics							
								Topology (object plan type)								Geometry (coordinates and indicators of object plan elements)								Qualitative		Quantitative					by Relation
								Simple			Composite					Simple				Composite											
			Name	Type (class)	Code	Value	by Attributes	Node	Line	Area	Set of Nodes	Tree (Set of Nodes and Lines 1)	Star (Set of Nodes and Lines 2)	Net (Set of Lines 1)	Polygonal divided Area (Set of Lines 2)	Point Identifier and Coordinates	Important Points of Line Identifiers and Coordinates	Important Points of Line Identifiers and Coor. Mark of Polyg.	Set of Points Identifiers and Coord.	Points Identifiers and Coordinates, Marks of Conjuction	Points Identifiers and Coordinates, Mark of Center Point	Points Identifiers and Coordinates, Marks of Conjuction	Points Identifiers and Coordinates, Marks of Conjuction	Binary	Nominal	Ordinal	Absolute value	Intervals of absolute values	Relative (ratio)	Intervals of relative values	Non spatial realation (hierarchy, element-component ...)
Identification by	Simple GU			i		i	i	x	x	x						x	x														
	Composite GU			i		i	i	x	x	x			x	x	x	x	x				x										
	GU Composition			i		i	i	x	x	x		x	x	x		x	x	x	x	x	x	x	x								
	Layer of GU			i		i	i				x	x	x	x	x				x	x	x	x	x								
	Simple GU + T		x	x	x	x	i	x	x	x						x	x	x													
	Composite GU + T		x	x	x	x	i	x	x	x		x	x	x	x	x	x	x			x										
	GU Composition + T		x	x	x	x	i	x	x	x		x	x	x		x	x	x	x	x	x	x	x								
Spatial semantic reference	GU Topology Reference	Figure					i	x			x	x	x	x		x			x	x	x	x									
		Line					i		x			x		x	x		x	x		x		x	x								
		Area					i			x		x	x	x	x			x	x	x	x	x	x								
	Graphic Operation Reference	R1					i				x		x			x	x		x		x										
		R2					i				x	x	x	x	x	x	x		x	x	x	x	x								
		R3					i	x	x	x	x		x	x	x	x	x	x	x	x		x	x								
		R4					i	x	x	x	x		x			x	x	x	x		x	x									
		R5					i				x		x	x	x	x	x		x	x	x	x	x								
		....																													
	Geometry reference	Top						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
		Top/Schem						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
		Schem						x	x	x	x	x		x	x	x	x	x		x		x	x								
Non-spatial semantic ref.	Graphic Variable Reference	Shape		i		i	i																	x	x	x					
		Size				i	i																			x	x	x	x	x	x
		Orientation				i	i																		x	x	x	x	x	x	x
		Color type				i	i																	x	x						
		Color intens.					i																			x	x	x	x	x	x
		Patern type				i	i																	x	x						
		Patern intens.					i																			x	x	x	x	x	x
	Graphic Operation Refer.	Geometric					i				x	x	x	x	x		x		x	x	x	x			x	x	x	x	x	x	x
		Color and Pattern					i				x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Topological					i					x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x

Explanation:

x - couple as a possible member of the designation function
i - designation implicitly distinguishable
GU + T - Graphic Unit signed by Text (alphanum. Identifier)

GU - Graphic Unit
R1 - aggregation (+ordering)
R2 - connection
R3 - connection/dividing
R4 - dissociation
R5 ... - boolean (is inside, covers, meets, overlaps)

Top - topographical reference
Schem - schematic ref.
to the math base of map

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Appendix: Frequency of semantic reference type in the map layer types based on the GU in distinguished thematic map layer in the map of Landscape Atlas of Slovak Republic and derived proposal of the graphic variable classification

Table 3a, 3b. Simplified point of view to the frequency of the map layer types based on the GU in distinguished thematic map layer in the map of Landscape Atlas of Slovak Republic

AQS	29	**LQS**	33	**FQS**	46
AMS	34	**LQC**	1	**FQC**	14
AQC	10	**LMS**	11	**FMS**	10
AMC	19	**LMC**	4	**FMC**	37
92		49			107
Sum of simple topol.ref.					248

A-LQS	89	**AL-FQS**	0	**A-FQS**	2	**L-FQS**	3
A-LQC	23	**AL-FQC**	2	**A-FQC**	0	**L-FQC**	2
A-LMS	79	**AL-FMS**	2	**A-FMS**	0	**L-FMS**	4
A-LMC	42	**AL-FMC**	60	**A-FMC**	2	**L-FMC**	10
233		64		4			19
Sum of integrated topology reference							320

Explanations: A – area topology reference, L – linear topology reference, F – figural topology reference
Q (M) – reference to the qualitative (quantitative) data type characteristic
C (S) – reference to the composite (simple) data type characteristic
A-L, AL-F, A-F, L-F reference to the integrated topology referenced graphic unit

Table 4a. Frequency of the map layer types and subtypes based on the GU in distinguished thematic map layer in the map of Landscape Atlas of Slovak Republic (datum for table 3a)

Area methods of the map expr.				
	Type	n	Subtype	n
	AQS	25	ABS	10
			ANS	15
	AMS	32	AOS	12
			AIaS	19
			AIrS	1
	AQC	7	ANNC	7
	AMC	14	ANOC	5
			AOIaC	8
			AOAC	1
	AAQC	3	AANNC	3
	AAMC	4	AAOOC	2
			AANIaC	2
Intermediary	A>FQS intp	4	A>FBS	2
Intermediary			A>FNS	2
Intermediary	A>FMS	1	A>FOS	1
Intermediary	A>FMC intp	2	A>FNOS	1
Intermediary			A>FOIaS	1

Figural methods of the map expr.				
	Type	n	Subtype	n
Point localized signs only	FQS	46	FBS	36
			FNS	10
	FQC	14	FNBC	6
			FNNC	8
	FMS	10	FOS	6
			FIaS	3
			FAS	1
	FMC	37	FBOC	1
			FNOC	13
			FOIaC	1
			FOAC	2
			FNAC	12
			FNIaC	6
			FIaIaC	2

Linear methods of the map expr.				
	Type	n	Subtype	n
Linea layers	LQS	33	LBS	19
			LNS	14
	LQC	1	LNNC	1
	LMS	11	LOS	10
			LAS	1
	LMC	4	LNOC	2
			LOOC	2

Q subtypes
B-binary
N-nominal
M subtypes
O - ordinal, Ia, Ir - interval
A - absolute value

Explanation: intp - area measurement as intensive value
expr.-expression

Note (about QS, QC, MS a MC types):

Simple (S) and composite (C) semantic reference of GU

413 thematic layers are based on the simple (S) graphic unit, 134 are based on the composite (C) graphic unit.

Semantic reference of Graphic unit to the qualitative (Q) and to the quantitative (Mint, Mext)

213 layers with semantic reference to the qualitative (binary or nominal) level of the reality description were distinguished.

91 layers with semantic reference to the quantitative level of the reality description were distinguished – comparison by intensity (M).

243 layers with semantic reference to the quantitative level of the reality description were distinguished – comparison by absolute value or interval of values (M).

Table 4b. Frequency of the map layer types and subtypes based on the composite GU or GU compositons in distinguished thematic map layer in the map of Landscape Atlas of Slovak Republic (datum for table 3b)

Area Methods with Line as Border of Area

	Type	n	Subtype	n
Line of map background	A(Lp)QS	14	A(Lp)BS	2
			A(Lp)NS	11
	A(Lp)MS	29	A(Lp)IaS	15
			A(Lp)IrS	10
			A(Lp)AS	4
	A(Lp)QC	6	A(Lp)BNC	1
			A(Lp)NNC	5
	A(Lp)MC	7	A(Lp)NOC	5
			A(Lp)OIrC	1
			A(Lp)IaIaC	1
Border as a outline of area	A(L)QS	51	A(L)BS	15
			A(L)NS	10
			A(L)OS	14
			A(L)IaS	10
			A(L)IrS	2
	A(L)QC	9	A(L)NNC	9
	A(L)MS	1	AA>F(L)MS	1
	A(L)MC	12	A(L)NOC	6
			A(L)OOC	5
			A(L)OAC	1
Area by line	(A)LQS	17	(A)LBS	14
			(A)LNS	3
	(A)LMS	12	(A)LOS	9
			(A)LIaS	2
			(A)LAS	1
	(A)LMC	1	(A)LOIaC	1
Integrted A and L type	ALQS	8	ALNS	8
	ALMS	37	ALOS	3
			ALIaS	34
	ALQC	9	ALNNC	7
			ALBNC	1
	ALMC	22	ALNOC	9
			ALOOC	2
			ALOIaC	10
			ALOIrC	1

Integrated methods over area

	Type	n	Subtype	n
Area with border and figural sign	(ALp)FMS	2	(ALp)FIaS	2
	A(L)FQC	1	A(L)FNBC	1
	A(L)FMC	4	A(L)FOOC	2
			A(L)FNIrC	1
			A(L)FIaIa	1
	A(Lp)FMC	54	A(Lp)OIrC	2
			A(Lp)OIaC	3
			A(Lp)IrIaC	47
			A(Lp)IaIaC	1
			A(Lp)IrAC	1
	ALFQC	1	ALFOOC	1
	ALFMC	2	ALFNIaC	1
			ALFOIaC	1
A and F	AFMS	2	AFOS	1
			AFIaS	1
	AFMC	2	AFNOC	2

Integrated method for nets and nodes

	Type	n	Subtype	n
Nodes	F(L)QS	2	F(L)BS	2
	F(L)MS	4	F(L)AS	4
	F(L)MC	1	F(L)NOC	1
Nets Nod.reg	FLQC	1	FLBBC	1
	FLMC	3	FLAAC	1
			FLOIaC	2
	LFQS	1	LFNS	1
	LFQC	1	LFNNC	1
	LFMC	6	LFNOC	1
			LFNIaC	1
			LFOIaC	1
			LFOIrC	1
			LFNIrC	1
			LFIaIaC	1

Explanation:

Q subtypes: B – binary, N – nominal

M subtyoes – O – ordinal, A – absolute value, Ia, Ir – interval of absolute or relative values

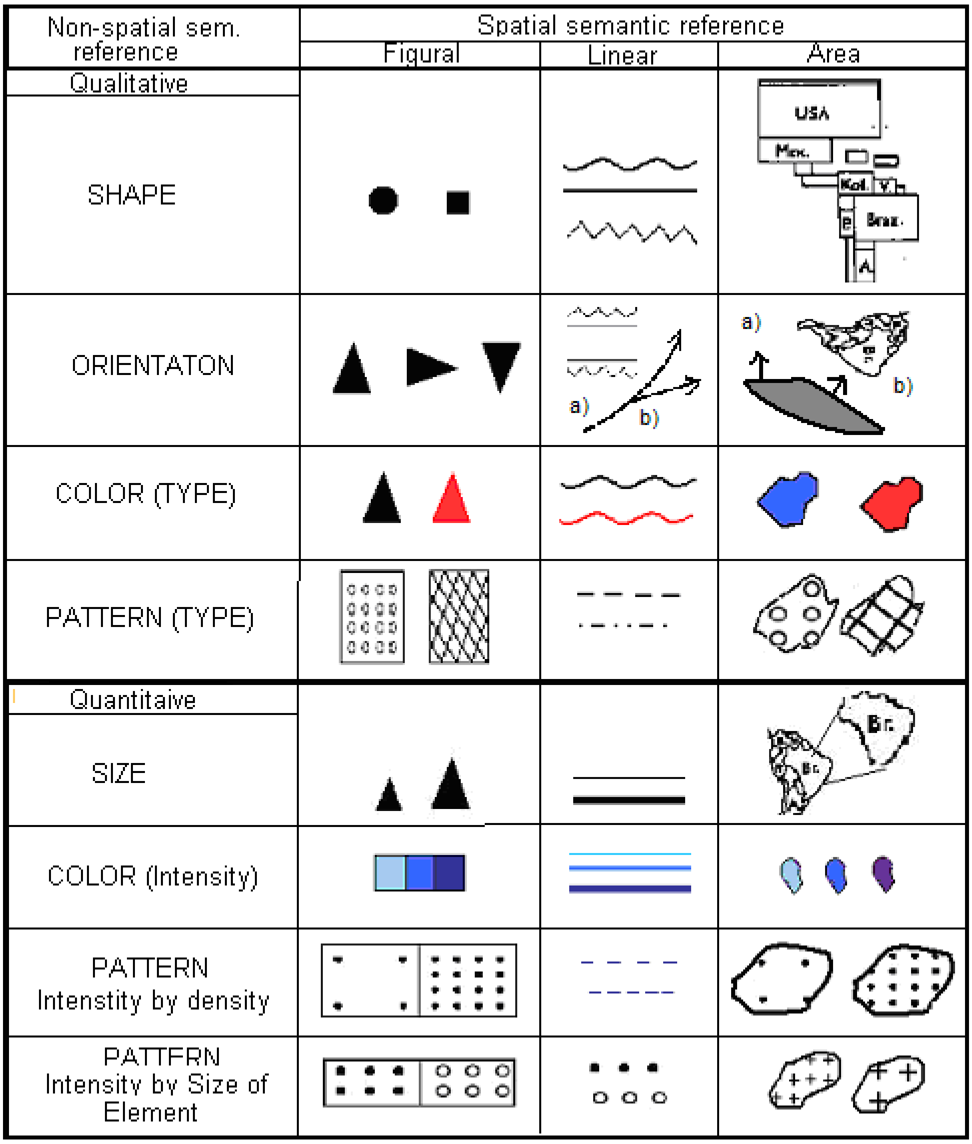

Fig. 4. Classification of the graphic variables by its semantic reference: a) non-spatial semantic reference – qualitative (Q) and quantitative (M), b) spatial semantic reference – figural (F), linear (L), area (A).