NSDI-compliant reference map: experiences on implementing a user-centered cartographic symbology and standardized data modeling at large scale (1:2000)

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Abstract. *Standardized urban maps are essential cartographic products to address the challenges of cities management. Brazilian NSDI (National Spatial Data Infrastructure) was created to facilitate geospatial data sharing and use, but its standards are not completely adapted for large scale mapping for urban areas. This work aims to propose data models and symbology based on existent standards to support the generation of reference maps at large scale (1:2,000) that is logically consistent, standardized and aligned to the principles of the theory of Cartography. These characteristics will allow these maps to be maintained by several producers, shared among institutions and, most importantly, understandable and meaningful for their users. The results of this project are a geospatial data model that includes some new classes & object, and their correspondent relations, needed in a large-scale mapping, and the related symbology for visualizing any map generated from that data model.*

1. Introduction

Although the legal base of the National Topographic Mapping in Brazil, the decree 243/67, only defines standards for systematic mapping at 1:25.000 scale and smaller, large scale reference maps are an important source of geoinformation to urban areas planning and management. According to the 2010 Census [IBGE 2010], 84% of Brazilian population lives in cities. An estimation from 2016 Brazilian population is that more than 94 million inhabitants live in 26 metropolitan areas with 1 million people or more [IBGE 2016]. This large population faces the issues that are common for cities around the world. In the UN-habitat 2016 World Cities report, the most important challenges are the growing number of urban residents living in informal settlements, the problem of providing urban services, climate change; exclusion and rising inequality and insecurity [UN-Habitat 2016]. Many of these challenges can be adequately addressed only when spatial data is available.

Large-scale standardized mapping is an important information source for the spatial analyses needed to propose solutions for urban management. Brazilian National Spatial Data Infrastructure (NSDI) was created in 2008 to facilitate geospatial data generation, use, and dissemination. However, the initiative is only mandatory for the Federal government, and, consequently, there are few examples of SDI (Spatial Data Infrastructures) in Brazil based on urban spatial data at state and local level government. The mapping of urban areas is the responsibility of local governments, and applying standards could help municipalities to exchange open format solutions to maximize the use of resources at the local administration level. State and federal level agencies, like the ones dealing with urban planning, can also take advantages from the use of standardized database models and cartographic solutions. Also, data sharing is crucial when dealing with adjacent urban areas, such as Metropolitan Regions.

This paper describes a research work that aims to propose a conceptual model, based on NSDI standards, and related symbology, for large scale (1:2000) mapping in Brazil. It is a part of an extensive research developed in the Cartography and GIS research group at the Federal University of Paraná.

Brazilian NSDI recommends that the product of reference mapping is a geodatabase which implementation must be based on the conceptual model called EDGV (in Portuguese, Estruturação de Dados Geoespaciais Vetoriais) [CONCAR 2010]. However, the latest version (2.1.3) of EDGV adopted by the National Commission on Cartography (in Portuguese, Comissão Nacional de Cartografia - CONCAR) is only suitable for 1:25.000 to 1:250.000. The Brazilian Army recently released another version, the EDGV Força Terrestre [DSG 2015], that, though not officially yet approved by CONCAR, detailed the data model at large scale.

Additionally, standard cartographic symbology is an important characteristic for any reference mapping. Although the digital technology allows us to use a high number of possibilities to interact with the geodata and to develop geoinformation analyses, the limitations of our (humans) visual perception and cognition is still a challenge in making the geoinformation visible. This issue is especially challenging as the standards for symbology are not yet updated for the NSDI environment.

The Brazilian reference mapping at large scales presents challenges related to symbology and database modeling. In this paper we describe a proposed solution for a conceptual model for a large-scale reference mapping and, also, a proposed set of cartographic symbols which solution is based on the EDGV classes and the T-34 700 Guide of Cartographic Symbols for Topographic Mapping at 1:25000 scales and smaller [DSG 1998]. The T-34 700 is an almost 20 years old guide, and although a representation standard is planned by DSG [DSG 2016], there is no official symbology specification aligned to the EDGV for any scale, including large scales.

To integrate the cartographic symbols to the EDGV classes by the theory of Cartography, we defined a set of cartographic features, and their classifications, that should be included in a large-scale reference mapping. In the second step of this research, we compared the EDGV and that list of classes and their definitions. We, then, designed a geospatial data model based on the identified similarities and differences. In the next step, we implemented this geospatial database for four cities in the State of Paraná. In the final step, we applied a proposed set of symbols to these datasets. Additionally, we stored the symbology using the OpenGIS® Styled Layer Descriptor (SLD) of the Open Geospatial Consortium [OGC 2007] to allow the utilization of the proposed symbology when the geospatial database is shared.

2. Materials and Method

This work began as a proposal for standard symbols for urban maps of the State of Paraná, Brazil. At that time, the graphic solution for topographic maps at large scales, 1:2000, 1:5000 and 1:10000 was not efficient, as we can notice in Figure 1. This kind of cartographic solution had been adopted in the State of Paraná, Brazil, for three decades as it was enforced by Paranacidade, the state-level agency for urban planning and development of the State of Paraná, Brazil. The State of Parana, through this agency, has funded reference mapping of several municipalities since the 1990s.

Figure 1. An example of the solution for topographic map symbols at 1:5000 scales in the State of Paraná, Brazil.

Hence, our research group proposed a new set of symbols for large scale base maps, as a consultant to a working group of the Technical Chamber of Cartography and Geoprocessing – (in Portuguese, Camara Técnica de Cartografia e Geoprocessamento – CTCG) of the State of Parana Government [CTCG 2009]. The first results of this project have been presented at ICC 2013 – International Cartographic Conference (Sluter et al. 2013). To achieve an efficient result in proposing the map symbols we developed a map design based on the theory of Cartography. Our first step was to set some premises as follow:

- The set of map features and their related symbols must be defined by the theory of topographic mapping.
- The large-scale maps must be totally integrated to the Brazilian standards for topographic mapping.
- Therefore, the decisions about symbols design must agree with the Brazilian standards for reference map symbols.

We defined the steps of the methodology by map design theory for generating topographic maps [Keates 1973], as follows:

- Defining the cartographic features that must be in a large scale (1:2000) reference mapping of an urban area.
- Establishing the meaning of every cartographic features based on the theory of topographic mapping.
- Grouping the features into classes by their meaning and by the EDGV conceptual model.
- Creating symbols for each kind of feature.
- Applying the symbols to urban areas of the State of Parana.

2.1. Study Area

We have tested all the results of this research work in four municipalities of the State of Parana (Figure 2). Those municipalities are Cascavel (24°57'21"S, 53°27'19"W), Guarapuava (25°23'43"S, 51°27'29"W), Ponta Grossa (24°05'42"S, 50°09'43"W) and São

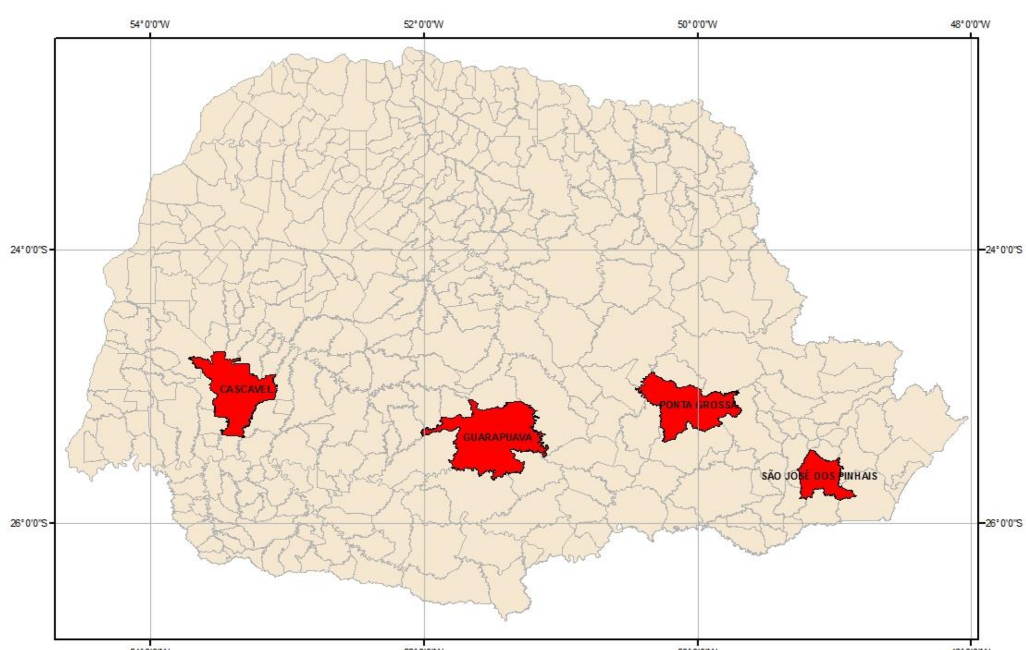

Figure 2. The State of Paraná, highlighting the studied areas.

2.2 Materials

We have been developing this research work using the following software:

- LibreOffice 2007 http://www.libreoffice.org/ - we used to generate the spreadsheets of definitions and symbology.

- Astah Community http://www.astah.net/ - we used this solution for the database modeling as UML class diagrams.
- PostgreSQL http://www.postgresql.org/ - with its extension PostGIS, we used this database management system to store the geographic database
- QGis http://www.qgis.org/ - we used this open source GIS software for data manipulation and definition of symbology. Additionally, we used the plugin DSG Tools created by the Brazilian Army to implement the EDGV model.

The large-scale topographic mapping (1:2000) was provided by Paranacidade in shapefile format.

3. Results

The results are presented in two sections: the first one describes the generation of the conceptual model for the reference maps and the database implementation, and the second one focuses on the symbology definition applied for the geographic database.

3.1. Data model

The definition of which cartographic features should be the represented at large scale topographic mapping is a result of several meetings with the members of the Technical Chamber of Cartography and Geoprocessing of the State of Parana, Brazil (in Portuguese, Camara Técnica de Cartografia e Geoprocessamento) [CTCG 2009]. After defining the cartographic features to be represented in topographic maps, we described the meaning of each one.

In the next step, we verified which classes are already part of EDGV data model, and which ones are not. We, then, grouped the classes were into EDGV categories: altimetry, recreation area, buildings, hydrography, infrastructure, boundaries, reference points, transportation, and vegetation. We organized a spreadsheet with symbology and definition of each class. This spreadsheet was the input to model the database with the relationships between objects in a logical structure as a class diagram. The conceptual modeling in UML focuses on the Class Diagrams for each category. Figure 3 shows an example of the diagram of the category *Boundaries*.

With the definition of all classes and categories proposed for a large-scale topographic mapping of municipalities under study, we defined the database scheme at the logical level. The results are the class diagrams and a general table that relate different classes and definitions from EDGV to the standards of CTCG.

We organized the general table as a set of spreadsheets. The spreadsheets refer to each category and, the first line of each specifies the category name and origin, which can be EDGV or CTCG. The first column of each spreadsheet shows the classes that compose it. The second column presents the classification criteria for each feature in the reference mapping. For example, in the *transportation* category, there is the "*Special Structures*" class in the CTCG standard, and several classes, e.g. Tunnel, Bridge, in the EDGV, therefore the classification criteria are different in both standards. The fourth column presents the definition of the feature. To be able to propose a solution for a geospatial data model based on both CTCG and EDGV, the differences between CTCG standards and EDGV for features definitions, classification, and classification criteria were highlighted.

Table 1 shows an example of a part of the relational table of the *Special Structure*s CTCG Class.

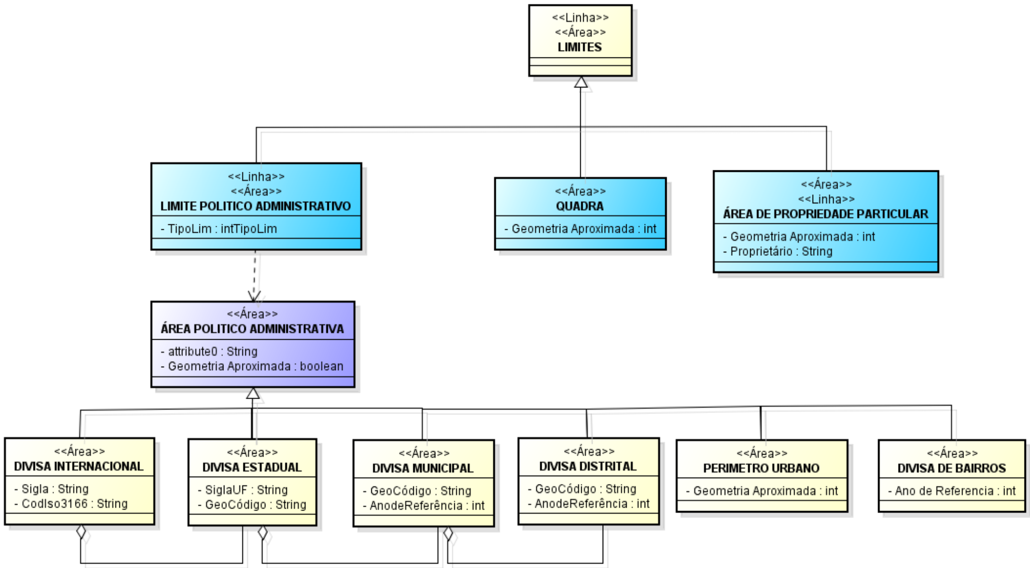

Figure 3. Class diagram of the category *Boundaries*.

CTCG			EDGV			
Classification criteria	**Feature**	**Definition**	**Class**	**Classification criteria**	**Feature**	**Definition**
Função como passagem de Nível no Sistema de Tráfego Terrestre	Túneis	Passagem ou caminho subterrâneo que serve de via de comunicação.	TUNEL	Altura	Túnel	Túnel é uma passagem subterrânea em uma via e no seu sentido longitudinal (Rodovia, Ferrovia, Dutos).
	Pontes	Construção que liga dois pontos separados por curso de água ou por uma depressão de terreno.	PONTE	Tipo de ponte/Vão livre horizontal/ Vão vertical/ Carga suportada Máxima	Ponte	Ponte é obra de arte especial destinada a permitir que uma via transponha um obstáculo líquido.

CTCG			EDGV			
Classification criteria	**Feature**	**Definition**	**Class**	**Classification criteria**	**Feature**	**Definition**
	Viadutos	Obra de construção civil destinada a transpor uma depressão de terreno, que não seja uma massa d'água, ou servir de passagem superior.	PASSAGEM ELEVADA/ VIADUTO	Tipo de Passagem/Viaduto /Vão livre horizontal/ Vão vertical/ Carga suportada Máxima/gabarito horizontal suportado/gabarito vertical suportado	Passagem Elevada/ Viaduto	Passagem elevada ou viaduto é uma obra destinada a permitir que uma via transponha vales, grotas, rodovias, ferrovias ou contorne encostas, bem como substitua aterros. Pode ser também uma via urbana para trafego rodoviário ou ferroviário em nível superior ao solo.
	Passagem de nível	Chama-se passagem de nível a um cruzamento não desnivelado entre uma ferrovia e um caminho ou estrada.	PASSAGEM DE NÍVEL	Nome	Passagem de Nível	Passagem de nível é um cruzamento de nível entre trechos rodoviários e um trecho ferroviário. Para efeito desta norma, também será considerado entre um trecho rodoviário e outro específico para o trânsito de Veículo Leve sobre Rodas.
	Pinguelas	Tronco ou prancha que serve de ponte sobre um rio.	TRAVESSIA PEDESTRE- Travessia de pedestre é uma estrutura, normalmente estreita, destinada a permitir a transposição, por pedestres, de um obstáculo natural ou artificial, geralmente construída sobre ou sob uma via.	Tipo de travessia de pedestres- Indica o tipo de travessia pedestre.	Pinguela	**A EDGV NÃO PREVÊ UMA DEFINIÇÃO DE PINGUELA**
	Passarelas	Ponte para pedestres,em geral estreita, construída sobre ruas ou estradas.			Passarela	**A EDGV NÃO PREVÊ UMA DEFINIÇÃO DE PASSARELA**
	Passagem a Vau	Local onde é possível atravessar o rio à pe, à cavalo ou de veicúlo traçado.		Tipo de travessia - Indica o tipo de travessia.	Vau construída / Vau Natural	Vau Construida: Travessia por região alagada ou massa d'água, após preparação especial. Também conhecida como "passagem molhada". Vau natural: Travessia por região alagada ou massa d'água, sem a necessidade de preparação especial.

Table 1. Relation (in Portuguese) of both conceptual models (CTCG e EDGV). Category: Transportation **and Class: CTCG** Special Structures **(Obras de Arte in Portuguese)**

We created the geospatial database using this reference table and class diagrams. In this step, we used the QGIS Plugin DSG Tools, a free and open-source solution that enables the generation of geospatial data in full compliance with the NSDI, which makes the physical implementation of the EDGV standard in the geospatial databases possible [DSG 2015].

After the creation of the geospatial database, we could transfer the features geometries from shapefiles, provided from Paranacidade to the corresponding tables in the databases. We had to manually assign the features attributes from the original data source to the corresponding EDGV data model when it was a complete relation with CTCG data model. When it was necessary, we created additional compliant classes and their attributes accordingly with the conceptual data model.

3.2. Symbology

After establishing the relation between both conceptual models, we could apply the proposed symbology to the EDGV-based geographic database. In Figure 4 there is a sample of the detailed symbology definition that we adapted to the new geospatial data model. The symbols' definition includes area fill and outline colors, fonts and point symbols.

SUBCLASS	FEATURE	GRAPHICAL PRIMITIVES	Fill		Outline			Font					Pontual symbol			
			RGB	Exemple	RGB	thickness	Exemple	Collor	Font	size	Text content	Exemple font	Collor	size (mm)	thickness (mm)	Exemple
EDIFICATIONS	Residentials and small size Commercial	A	255,190,190		255,0,0	0,18 mm		-	-	-	-	-	-	-		
	Nursing Homes and Rest Homes, Orphanages, Social Action Centres	A	255,190,190		255,0,0	0,18 mm		0,0,0	Arial	6	Institution name	REST HOMES	-	-		
INDUSTRIAL EDIFICATION	Industrial and Operations Edifications, Warehouses, Silos and Industrial Shed	A	156,156,156		0,0,0	0,18 mm		0,0,0	Arial	6	Industry name	BOSCH, SUBESTAÇÃO COPEL, ETA SANEPAR	-	-		
	Chimneys	P	-	-	-	-		0,0,0	Arial	6	CH	-	0,0,0	4		
PUBLIC ADMINISTRATION EDIFICATIONS	Public administration , municipal, statual and federal edification	A	255,211,127		255,125,0	0,18 mm		0,0,0	Arial	6	Public Institution name	PREFEITURA	-	-		
EDUCATIONAL INSTITUTIONS	municipal, state and federal educational institutions,.	A	255,190,190		255,0,0	0,18 mm		0,0,0	Arial	6	Institution name	COLÉGIO ESTADUAL DO PARANÁ	0,0,0	4		
TEMPLES RELIGIOUS	religious temples; cemetery Buildins, and mortuary chapels..	A	255,190,190		255,0,0	0,18 mm		0,0,0	Arial	6	Local Name	IGREJA SÃO JOÃO	0,0,0	4		
HEALTH CARE	hhospitals, clinics and health posts	A	255,190,190		255,0,0	0,18 mm		0,0,0	Arial	6	Institution name	HOSPITAL DAS CLÍNICAS	255,0,0	4		

Figure 4. Symbology description adapted to the conceptual model (in Portuguese).

We applied the standard symbology to the datasets of the four municipalities we have chosen as study areas (Figure 5 e 6). We exported the resulting symbology using SLD style to be used in data sharing applications, for example, servers of WMS (Web Mapping Services).

Figure 5. Extract of the results for the city of Cascavel

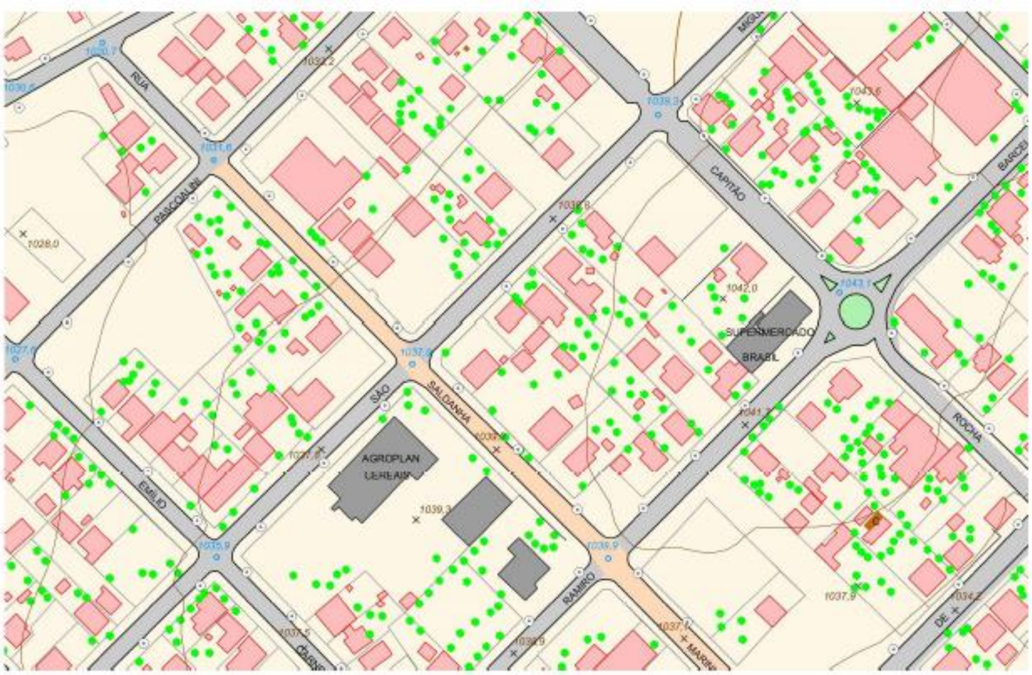

Figure 6. Extract of the results for the city of Guarapuava.

4. Conclusion

The standardized geodatabase and symbology of the data that compose the large-scale reference mapping guarantee the interoperability amid systems at different social and political levels (local, state or federal). The standardization enables the integration between different geospatial databases, which is an important result of this work in planning, engineering, and urban projects. The standards for geospatial database and symbology make spatial data review and update possible, minimizes the time for spatial analyses, and ensures information quality.

The main obstacles to developing this work were the data models discrepancies since EDGV and CTGC standards were proposed for different purposes in different time. The plugin DSG Tools facilitated the process to create EDGV compliant database and shows how the development of open source tools can be a benefit for several uses on a standardized environment.

The solution proposed in this research can be implemented in any geospatial database at 1: 2000 scale and using it at other scales could be adopted with some adjustments in the method. More users could be involved in the conceptual modeling and testing steps to expand the use out of the Parana context where we developed this the research work. The proposition and management of standards is a continuous task. Several studies on cartographic generalization, geospatial semantics, user's cognition and others can benefit from the results of this conceptual model.

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