Digital Cartographic Generalization for Database of Cadastral Maps

Mariane Alves DAL SANTO, Brazil
Carlos LOCH, Brazil
Francisco Henrique de OLIVEIRA, Brazil

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SUMMARY

Potential users of Geographic Information Systems (GIS), among them private companies and public institutions, have different necessities in terms of quality, quantity and type of data stored in the spatial database, especially in the development of their land planning and management. With the recent city halls computerization process, the Geographic Information Systems represent one of the most important tools for manipulating cadastral data. The Cadastral Cartography has benefited from this technology, once it needs mapping in different scales which serve the prerogatives of the Multipurpose Technical Cadastre and the territorial management. Currently, the automated cartographic generalization is one of the most utilized techniques in the scale transforming of geo-referenced geographic data. In this context, this paper aimed to develop methods of cartographic generalization using GIS. Thus, the generalization models were generated, evaluated, and presented through different criteria. Among these criteria**,** the structure of the digital data storage, the effectiveness of the recovery operations in the generalization process, and the necessity of a spatial perception for applying the operations. This study used the Criciuma cadastral cartographic base maps (scale 1:5.000, year 2003). The method was applied through the following steps: evaluation of the scientific and technical knowledge development in the cartographic generalization, development of automated cartographic generalization models, the applying of generalization processes, multi-scale spatial data base generation (1:10.000 and 1:25.000), evaluation of the geometric and topological quality data derived and finally, validation of the methodology as a support to territorial planning and management.

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1. INTRODUCTION

The development of geomatics surveying is of extreme importance, because it is the reference for all the integrated geographical information are on the same frame map, as well as the easy identification of information and their position relationships, on the Earth's surface.
The Cartographic base must be drawn up in order to represent accurate and detailed position, shape, dimensions and the identification of land accidents. It must provide the relations metrics like: distance, angles, manipulated and areas of elements geographical map, as described in the Cartographic projection used.
The degree of accuracy and detail is linked directly to the scale of graphical representation, be it on paper or through video monitor, as well as by the end of the document map.
The Cartographic compilation method is the construction of a letter from other cartographic documents existing. The scale of these documents can be greater than or equal to the charter be built. This method can be used both in the development of new letters on the existing update.
In IBGE (1996), the build is done, by two separate processes:
a) Compile – when compilation is made from documentation on the same scale of the final product desired.
b) Compilation by reduction – may be made by:
Direct reduction – when documentation be used is reduced to the scale of the Charter to be produced. Later the reductions are mounted on a network location, projection and scale adopted for the Charter to be produced. Then the final document is drawn up.
Prior selection – all interest in Charter are selected from the documentation Basic. Then the generated documents are reduced to the scale of the Charter in preparation.
This build process for reduction, which determines the application, is the density of elements in the area of Letter to be drawn up. The first way, direct reduction is recommended for the areas of low density details and, second, provided for selection areas with a high density of details.
Description of both methods is that a letter is only reduction real world elements to represent them in dimensions on the which can be processed and analyzed to meet a given purpose. The spatial objects are abstracted reality to be mapped and processed by processes, cartographic containing data and information that may be interpreted by the user. These information generated are obtained from transformations applied to the original data, are they obtained directly from the real world or pre-existing letters, and processing of scales, the transformation of the area curvilinear in flat and the transformation of spatial objects that symbols representing them. From the moment that there are transformations occur decrease in the ability to display details and information characterizing a generalization process.

In the digital environment, with the use of GIS, data structure determines its use and consequently the success and relevance of the application. This means the real world can be described only models that outline the concepts and procedures needed to make real-world observations in the data that will be handled in GIS. In a geographic database, this modeling is expressed in five main elements.

To build the real world in a GIS use simplified models of reality, where phenomena can be classified and described. After they are converted into a data model where they are applied geometry and quality elements. This data model is transferred to a database in digital medium, where data can be submitted and viewed on maps or representations.

Davis and Laender (2000) highlights that the concern to implement processes similar to those traditionally employed in cartography is reflected in the architecture internal and database schema adopted in most commercial GIS. With the intention to preserve the user's familiarity with the conventional appearance natural phenomena or built by man, technical private database organization are incorporated to GIS, making it difficult to conceive of spatial information systems.

This way the above authors introduce the concept of multiple representations in GIS, based on the existence of a primary representation that can be used to generate some or all of the other, secondary representations, called through processing operations appropriate. The primary representation should be more detailed and comprehensive all representations that were outlined in the conceptual representation, and is the only one that can be changed by the user, using as the strategy derivation of data. Secondary representations generated from this through processing operations are stored to avoid reprocessing. Each modification or update of a primary object produces a demand for update, which is an object which records the nature of modification and indicates the need of regeneration of secondary objects match.

According to John (1998), in the context of digital mapping how the generalization affects statistics and geometrics properties of spatial data is critical for GIS users.

In this context, the digital cartographic generalization has become a growing concern when using GIS for generation of spatial databases and maps.

This way, to give start this work, it was necessary to develop focused scientific research the cartographic problem solution, suggesting solutions that mitigate cartographic production costs and enhance tasks.

According to John (1998), for the generation of systems cartographic targeting service projects that have goals from a panning up assessments located, it is vitally important that use the latest technological resources of the area, is the Cartographic generalization to optimize resources in implementing various cartographic products scales, is the use of tools for the confrontation of different levels of information, which can be completely resolved with the use a SIG, among many other technological resources.

This work, the procedure used for the generalization process optimization was coupled spatial data to quality source database and resources offered by the software.

The region defined as the area of interest search, development was the municipality of Santa Catarina, Criciúma – due to its cartographic history, i.e. availability of mappings in the digital environment, 1999-2004, scale 1: 5000, developed through aerofotogrametry and techniques as well as database cartographic generalization generation cartographic scale 1: 5,000 to scales of 1: 10.000. However, another very factor important should be taken into consideration in the definition of the area of interest Search. The region North of the municipality of Criciúma presents itself as a region of great potential to urban occupation.

2. DEVELOPMENT AND IMPLEMENTATION OF A TEMPLATE FOR NETWORK GENERALIZATION

The model to be described is the method for network generalization, shown in Figure 1.

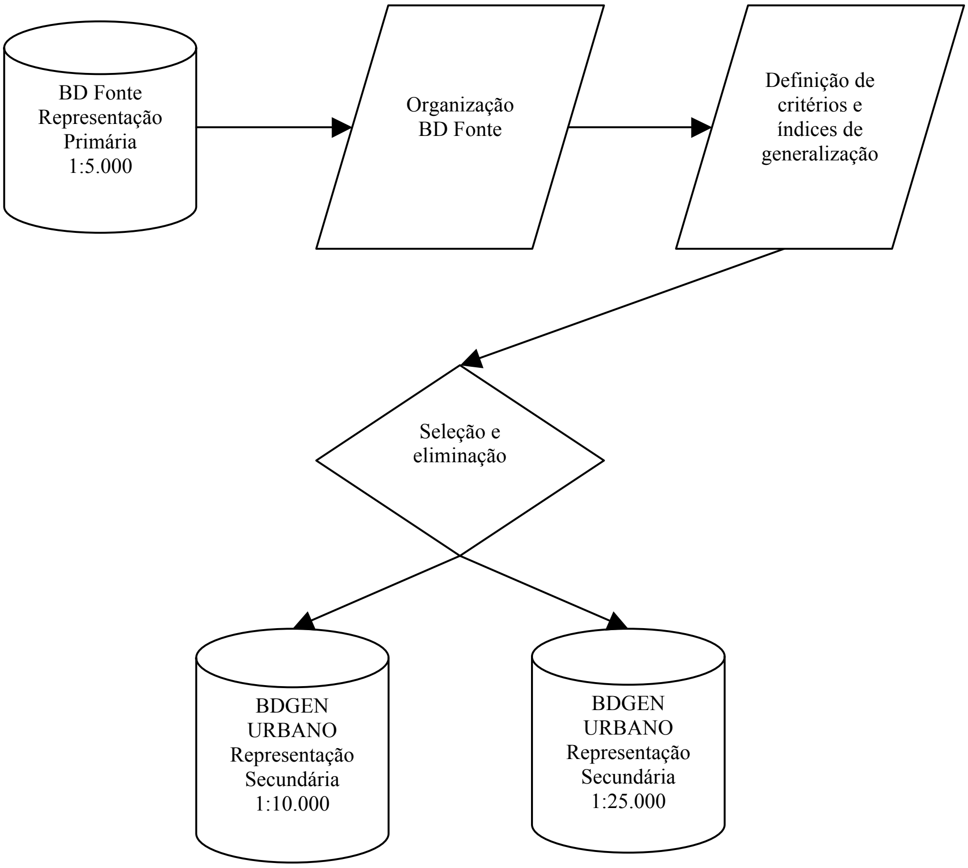

Figure 1 – Generalization model chart

The method developed the goals:
a) Decrease visual elements density in certain scales;
b) Maintain the topology between the elements;
c) Keep the geometry of the elements in relationship to the original database (the primary representation).

The following describes the steps in the model development.

2.1 Organization and analysis of the source database

The first step was to select layers to relevant network representation, on the scale 1: 5000 is represented by listed layers in Table 1, with their respective characteristics of representation.

FID	*ENTITY*	*LAYER*	*COLOR*	*LINETYPE*	*WIDTH*
1	polyline	5102_Rua sem Pavimento	7	Continuous	1,0
2	polyline	5102_Caminho	1	Continuous	1,0
3	polyline	5103_Eixo de Logradouro	2	Continuous	1,0
4	polyline	5903_Limite de Setor	8	Continuous	1,0
5	polyline	5102_Rua Pavimentada	7	Continuous	1,0
6	polyline	5735_Cerca	1	Continuous	1,0
7	polyline	5101_Quadra Definida	6	Continuous	1,0
8	polyline	2301_Lote	7	Continuous	1,0
9	polyline	5734_Muro	7	Continuous	1,0
10	polyline	5739_Muro de Arrimo	7	Continuous	1,0
11	polyline	5101_Rodovia - Estrada Pavimentada	1	Continuous	1,0
12	polyline	5504_Quadrícula de Coordenada	7	Continuous	1,0
13	polyline	5904- Limite de Bairro	8	Continuous	1,0

Table 1 - *Layers* of urban network

2.2 Criteria for the network generalization

It was considered the precision parameters graphics, stipulated by national legislation-IBGE (2007) and technical standards, ABNT NBR 13133 (1994) which considers the smaller perceived by the human eye graphics and smaller able to be represented on a map. According to NBR 13133, minimum can be accurately the eye is 0, 2 mm as the graphical error measurements can be known, by applying the following relationship:

$$Q = 0,2 \text{ mm} \times N \quad (1)$$

Where: scale is the denominator.

The graphics are details whose dimensions below the error defined by the criteria previously set will not have graphical representation and will be deleted from the report.
However, the T34-700 (technical manual DSG, 1998), (first part) which deals with the standards for employment of symbols, in its chapter 2 - Transport system: 2ð4. Representation, stipulates that ... (7) scales of 1: 25.000, 1:50.000 and 1: 100.000 in regions of good road network density, should only be represented if they are of length, greater_or_equal the 1 cm.
In this way adopts an adaptation of accurately described previously, whose values are presented in Table 2.

Table 2 - Calculation of selection criteria and Elimination lines network

SCALE	*N x 1 cm*	*Smaller size*
1: 10.000	10.000 x 1 cm = 10.000 cm	10 m
1: 25.000	25.000 x 1 cm = 25,000 cm	25 m

Within the parameters lay down in the table, developed "scripts":

(a) to scale 1: 10.000, the function “select” linked to “analysis tools” the arctoolbox and developed a “script” - “Length” <= 10 m”, which applied to layers and deleted all the elements less than 10 meters.
(b) to scale 1: 25.000, the function “select” linked to “analysis tools” the arctoolbox and developed a “script” - “Length” <= 25 m”, which applied to layers and deleted all the elements less than 25 meters.

Thus a decrease in density the information, without losing the geometry of the elements, as can be noted in Table 3.

Table 3 – Representation of the density of layers after generalization

Layers	*Escala 1:5.000*	*Escala 1:10.000*	*Escala 1:25.000*
Cerca	336 arcos	257 arcos	166 arcos
Eixo de logradouro	525 arcos	446 arcos	316 arcos
Limite de bairro	3 arcos	3 arcos	3 arcos
Limite de setor	13 arcos	13 arcos	13 arcos
Quadra definida	65 arcos	60 arcos	58 arcos
Quadra indefinida	2 arcos	2 arcos	2 arcos
Lote	593 arcos	360 arcos	44 arcos
Muro	143 arcos	80 arcos	34 arcos
Rua pavimentada	114 arcos	101 arcos	84 arcos
Caminho	168 arcos	140 arcos	90 arcos
Rua sem pavimentação	270 arcos	227 arcos	202 arcos
Rodovia estrada	2 arcos	2 arcos	2 arcos
Muro de arrimo	46 arcos	23 arcos	7 arcos

The following is a visual comparison between the layers utilization the original (primary) representation and layers resulting from generalized database (secondary) representation in certain scales (Figures 2 to 5).

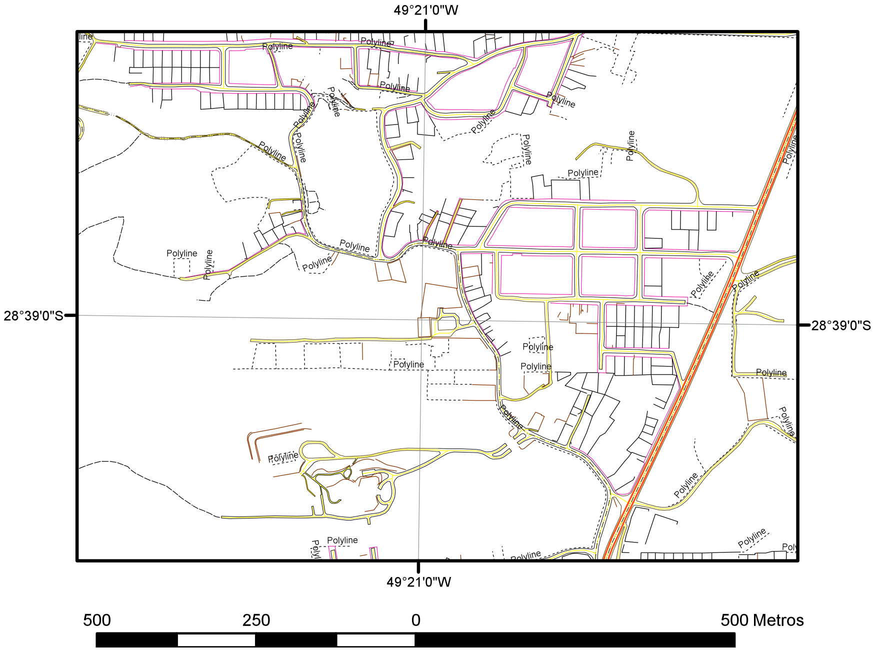

Figure 2 – View layers original database network
(primary representation) - scale 1: 10.000.

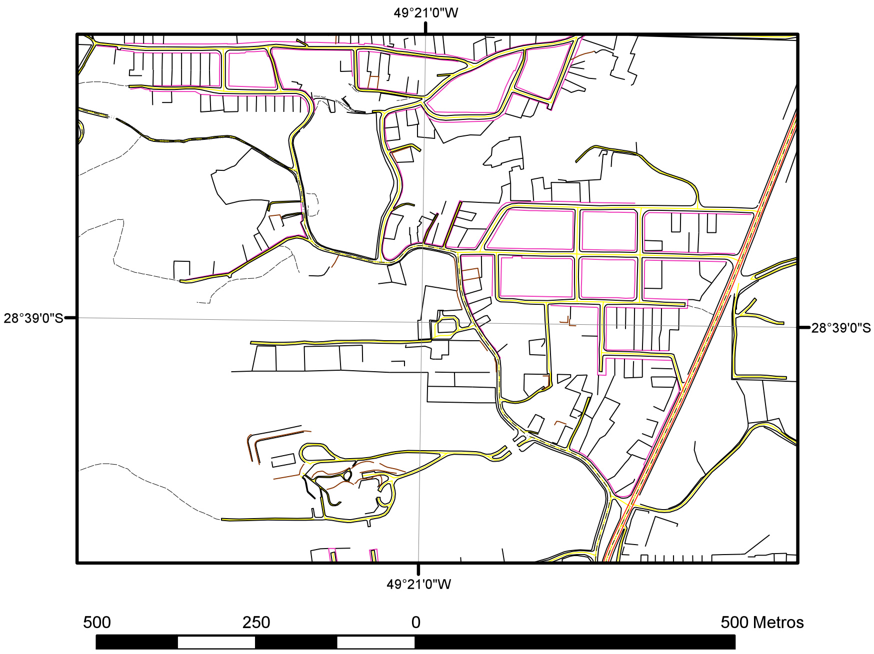

Figure 3 – View layers of network database
Scale 1: 10.000 (secondary) after application representation
the generalization parameters.

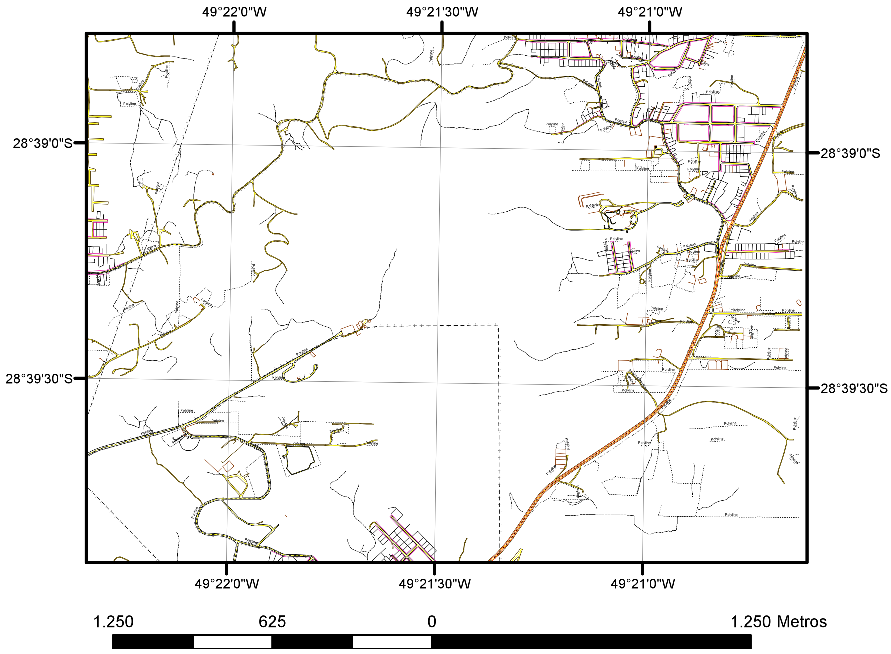

Figure 4 – View layers original database etwork
(primary representation)-1: 25 000 scale.

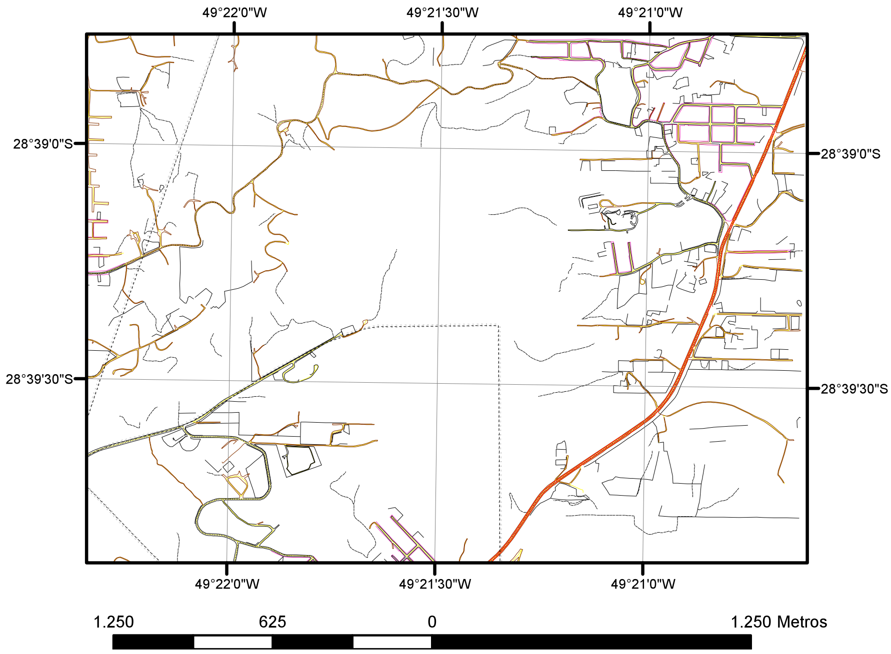

Figure 5 – View layers of network database
Scale 1: 25.000 (secondary) after application representation generalization of parameters.

3. ASSESSMENT AND ESTIMATE THE QUALITY OF PRODUCTS GENERATED

The process of generalization can cause unpredictable effects on metrics, topological and semantics of the data.
John emphasizes (1998) the length of the internationalization features usually decreases, but can also increase, with the reduction of scale. In addition, stresses that these changes (side plane, angular, etc.) affect the environmental studies involving GIS in mappings different scales.
According to Bard (2004), the process of evaluation of generalized data passes through a visual assessment of the outcome, an evaluation of changes in geometric primitives (surface) line, and an integrated automatic evaluation.
As the evaluation of geometric primitives, the lines are, without doubt, the most important evaluation objects. Objects linear represent 80% of the internationalization features a map: roads, rivers, curves level, railways, limits, etc.
The assessment of quality of generalization of a line can be decomposed into five types:
a) Rules space: relating to the façade and topology;
b) Quantity information: this measure assesses data reduction rate;
c) Accuracy geometric: this measure aims to compare the relative positions of two rows by direct comparison of geometries;
d) Conservation geometric properties: the linear stipulated have certain properties implied.
e) Maintenance forms: the goal is to assess the degree of degradation of line or of a curve.
With respect to information density evaluate the type stipulated planimetrical line method by Lazzarotto (2005), which uses fuzzy logic and creates an indicator Planimetric Generalization in the ratio scales establishing cartographic generalization quantitative criteria. The following describes the method of valuation model urban network generalization.

3.1 Definition of evaluation criteria

As the network generalization method was network a geometric transformation not occur and the topological elements, but only to decrease the density of data representation adhering to national geomatics legislation parameters for accuracy, and the values laid down in the T34-700 (Technical Manual DSG, 1998) the analysis and evaluation of generalization of data developed a method, adapted Lazzarotto (2005) that takes into account the relationship between scales to assess quantitatively the results.
Assuming this relationship developed a generalization index (*GI*) defined by the relationship between the denominator source scale and widespread scale denominator via the formula:

$$Ig = Do/Dg \qquad (2)$$

Where:
Do– the denominator source scale;
Dg– the denominator widespread scale;

From this index, and knowing the number of elements represented in the source scale (Xo) calculate the actual amount of elements to be represented in the scale widespread *(Xgr),* via the formula:

$$Xgr = Xo * Ig \quad (3)$$

3.2 The application of evaluation

The first step was to add the assessment number of rows in the scale 1: 5000 (primary production) and the number of resulting rows in generalized scales (secondary) representation.
The second step was the application of the formulas described above; the results are presented in Tables 4, 5 and 6.

Table 4 – a result of calculations for 10 000 scale.

Arcs	*Xo 1: 5000*	*Xg 10.000*	*Ig =/Dg*	*Ig Xg = Xo **
Total	2280 arcs	1714arcs	0,5	1.140arcs

Table 5 – a result of calculations for 1 000 scale.

Arcs	*Xo 1: 5000*	*Xg 1: 25.000*	*Ig =/Dg*	*Ig Xg = Xo **
Total	2280 arcs	1021arcs	0,2	456 arcs

Table 6 – General result for assessment the generalized scales

Do	*Dg*	*Ig*	*If Xo = 2280 Xo Xg = Ig * Type(typical)*	*Sub-gener. Xo Xg = 2Ig * (Maximum)*	*Super-gener. Xg = (1/2) Ig * Xo (Minimum)*
1: 5,000	10.000	0,5	1140	2280	570
1.5.000	1: 25.000	0,2	456	912c(2)	228

3.3 Analysis of the results

After the quantitative assessment concluded that the scale of 1: 5000 to 1: 10.000, the value of 1714 arcs achieved with the methodology used, is 50% above the average value that is the 1140 arcs, 25% below the maximum value of 2280 (resulting from 2Ig = 1) and 200% above the minimum value of 570.
The scale of 1: 5000 for 1: 25.000, where there is a greater density of elements, the value of 1021 arcs achieved with the methodology used is 123% above the average value that is the 456 arcs, 11% above the maximum value and 347% arcs above minimum value of 228 arcs.
As already noted above, in cases there is a large distance between the elements, there may be situations in which in cartographic generalization process is possible representation of a

quantity of elements greater than the one established by ceiling, given by *Xgr=2Ig*Xo*, or even all of them represent, as in the case of 1: 10.000 scale reduction in that 2Ig = 1 .

This way it is concluded that despite the method adopted, decrease visual elements density and maintain its geometry, within the parameters specified by national cartography, the elements for the network require a subjective analysis for determination of its representation in ticks defined, since realize greater difficulty maintaining their topology. For the processing of scale 1: 5.000 to 1: 10.000 found that the methodology was satisfactory once the elements contained in the scale 1: 5000 may be represented in scale 1: 10.000, and within maximum parameter generalization adopted in evaluation.

In reducing the scale of 1: 5000 for 1: 25.000, scalar processing occurs due to a larger, more the concentration of elements for a smaller unit of area, it was found that the check operations using national legislation parameters were not sufficient and suitable for optimized of representation data. Whereas a map does not represent the entirety of phenomena space, and plays only some of them should take the cartographer always take account of the intended purposes.

McMaster & Shea (1992) consider selection as a preprocessing stage for geometric transformations and topologies. The generalization occurs after the selection process. It was noted that although identify and minimize geometrically, with the application of cartographic generalization operators stood still need to perform again the selection process, in other stipulated that needed to be deleted, whereas the entire map.

Second Nalini (2005), for urban management is important to acquire a Cartographic base derived enterprise wide area under management, which has a specialist view clear and readable. Therefore the assessment of this users definition of information that must be represented and on the basis geomatics derivative is essential, if we do not achieve the purpose of map and the user deployments–especially the whole process of abstraction and cartographic generalization must be done again, until it reaches its goal is to Cartographic communication. The definition of when and how to perform the process is very subjective and depends on the experience of every professional involved, and as mental map is generated, i.e. as professional process and the user sees the reality. As soon as the difficulty of establishing rules for the Cartographic generalization process too complex.

This way, to the maintenance of the relationship topological between elements and present a satisfactory visual density is select the most representative layers within the scale 1: 25.000. After this subjective analysis and visual Database widespread have select and delete the layers. After the removal resulted arches, or is a value that is quantitatively categorized between the maximum and average generalization value for the transformation of the scale of 1: 1.000 to 1:5.000.

Table 7 – selection and elimination of layers generalized composition of the database in the scale 1: 25.000

Layers	*1: 25 000 Scale.*	*Operator*
Cerca	166 arcs	Elimination
Eixo de logradouro	316 arcs	Elimination
Limite de bairro	3 arcs	Selection
Limite de setor	13 arches	Selection
Quadra definida	58 arcs	Elimination
Quadra indefinida	2 arcs	Elimination
Lote	44 arcs	Elimination
Muro	34 arcs	Elimination
Rua pavimentada	84 arcs	Selection
Caminho	90 arcs	Elimination
Rua sem pavimentação	202 arcs	Selection
Rodovia estrada	2 arcs	Selection
Muro de arrimo	7 arcs	Elimination

The below the visual representation of the result of scale 1: 5000 to 1: 25.000 (Figure 6).

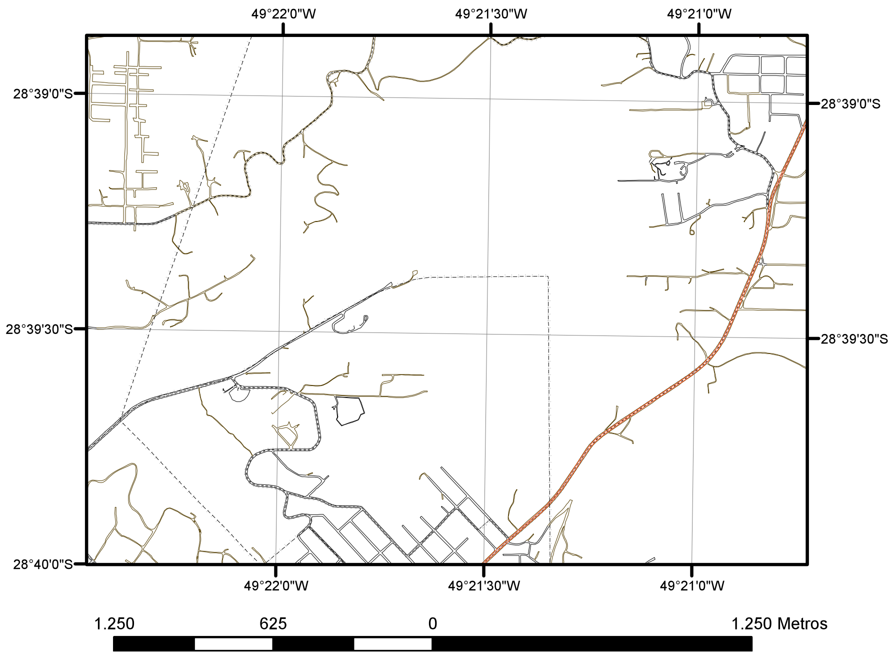

Figure 6 – view *layers* urban network in the scale 1: 25.000 secondary (representation) after the reclassification

As can be seen in Figure 6, the degree of generalization of information corresponds to what is possible, of the element in question true greatness. As the map 1: 25.000 scale derived aims to represent general aspects of the movement and serves as a fund reference for representation of other themes used for the planning, to assess this explosion remember here the length of the ground, where 1 cm corresponds to 250 m. were excluded in the new selection process fences, walls, lots, which were considered stipulated with information specific to a particular subject and are not suitable to this scale, because geometrical condition and the places axes and by overlapping paths are already represented in the streets and internationalization features roads.

4 Conclusions and recommendations

The development of the methodology was based an intuitive and interactive process to coordinate the different stages of work to be performed. The adoption of procedures to respond to concerns required that reflected the objectivity of the form answer if steps generation, analysis and evaluation, through verification results not matched the prerogatives of a spatial database automated load itself parameters of autonomy, flexibility and maintenance, a process of municipal planning and management.

After the development and evaluation of the method, it was found that the generated models were satisfactory for the purpose aim, i.e. generating widespread spatial databases to from the original database, allowance and support municipal planning.

As the use of GIS, this contacted streamlines the process of generalization. Implement a simple implementation of algorithms no answer 100% generalization of elements. This approach is still necessary analysis found the results and cartographer interference in the final result of generalization.

Regarding the products, in the form of widespread databases, it emerges that followed the principles of accuracy, decrease the density of information and relations topological.

Looking to develop a model that can be applied to other locations, and with the use of other software, study area for the development of this work, provides various elements of the occupation. In this way using these models, can become viable application by the change of values as the presentation of elements and the desired scale.

It is recommended that databases for the automated generalization are prepared within topological and criteria to facilitate the application of geometry of generalization operators. Examples this can be cited, as a careful vectorizer elements, looking for respect their topological relations, completeness and accuracy of values.

Recommends the development of databases multi-scale data, where each scalar representation is determined by its features, ease of handling and updating of databases data.

In view of the above, it is of capital importance to the continuity of ongoing activities as well as the development of new methodologies, implementing the procedures, with a view to addressing the main needs and issues relevant to today's GIS, as tools that can provide, in addition to automated, cartographic production support a geographical information system in all its extension. Between the those: Data acquisition geography of different origins: scanning, satellite images, among others; Portability and interoperability – integration of disparate systems and data in different 2D/3D formats; Metadata creation connect with relational databases; Rule definition topological and spatial restrictions – guarantee consistency and integrity of database and considerable increase in productivity with better quality; And finally the spatial data availability, represented by corporate networks prefectures and public or private institutions, and in the worldwide network of computers (World Wide Web), through various forms and modern technologies such as: PDA +, Mobile Phone, Wireless Handheld, Cam WAP, among others.

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BIOGRAPHICAL NOTES

Mariane Alves Dal Santo

Graduate at Geografphy from *Faculdade de Filosofia Ciências e Letras Imaculada Conceição – Brazil* (1986), master's at Geography from *Universidade Federal de Santa Catarina - Brazil* (1993) and ph.d. at Civil Engineering from *Universidade Federal de Santa Catarina - Brazil* (2007). Has experience in Geosciences, focusing on Geo-cartography, acting on the following subjects: geographic information systems, geoprocessing, environmental analysis, geography and remote sensing.

Carlos Loch

Master's at Geodesics from *Universidade Federal do Paraná – Brazil* (1982) and ph.d. at Forest Resources and Forest Engineering from *Universidade Federal do Paraná - Brazil* (1988). Has experience in Civil Engineering, acting on the following subjects: cadastre, urban planning, geoprocessing, remote sensing and environmental analysis.

Francisco Henrique de Oliveira

Has graduation at Engenharia Cartográfica by *Universidade Estadual Paulista Júlio de Mesquita Filho - Brazil* (1993) , master's at Engenharia Civil by *Universidade Federal de Santa Catarina- Brazil* (1995) and Ph.D. at Engenharia de Produção by *Universidade Federal de Santa Catarina - Brazil* (2002) . Has experience in the area of Geoscience , with emphasis on Geodesy. Focused, mainly, in the subjects: Digital Photogrametry, Geoestatistic, Geometric Quality.

CONTACTS

Mariane Alves Dal Santo
Universidade do Estado de Santa Catarina - UDESC
Avenida Madre Benvenuta, 7000
Florianópolis
Brasil
Tel. +55 4833218542
Fax +55 4833218500
Email: marianedalsanto@udesc.br
Web site: http://www.geolab.faed.udesc.br