Generalized map production: Italian experiences

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Key words: Intesa GIS, Topographical DB

SUMMARY

The research on production of generalized cartographic representations from, available, larger scale data concerns the field of cartography from the beginning of the numerical productions: the possibility of obtaining synthetic bases by simply "mixing" the most detailed and / or updated representations should be subject to the attention of all maps producers, with the aim of increasing optimization of information flows and better use of available funds.

The transition from “simply numeric” base maps to the current Topographical DB now allows both to work on data with a rigorous topological structure of contents that enables both the design and implementation of "intelligent" mechanisms capable of acting automatic choices closer with those traditionally performed by the cartographer at the time of traditional map redesign, and shareable and reusable tools, to be also applied in different application contexts, given the distribution of shared data models (between different Regional Administrations), compatible at different scales.

The idea of producing spatial information from the larger scale, close to Municipalities which are in charge of managing, coordinating and implementing territorial changes, and then obtaining the synthetic representations by acquiring data and producing updated maps is nothing new, but only in recent years, with the spread of powerful computer equipment, but especially with databases that have been oriented to information systems, what is carried out in the academic and research fields can find real applications, perhaps encouraged by current economic trends that invite everyone to pursue the sustainability of investments.

This paper, starting from the experiences of authors, in nineties, on cartographic production, resumes, in a topological approach, generalization procedures applied on base maps produced through IntesaGIS regulations, by original algorithms aimed at producing deliverables compatible with ordinary representations.

RIASSUNTO

La ricerca sulle produzioni di rappresentazioni cartografiche generalizzate a partire dai dati disponibili a scale di maggior dettaglio interessa il settore della cartografia fin dall'inizio delle produzioni numeriche: la possibilità di ottenere basi di sintesi semplicemente "frullando" rappresentazioni più dettagliate e/o aggiornate non può che essere oggetto delle attenzioni di tutti i produttori di cartografia, nelle ottiche sempre più attuali di ottimizzazione dei flussi informativi e di migliore utilizzo delle disponibilità economiche.

Il passaggio dalle basi cartografiche semplicemente "numeriche" agli attuali DB Topografici consente oggi sia di poter lavorare su dati con una rigorosa strutturazione anche topologica dei contenuti, che consentono l'ideazione e la realizzazione di meccanismi "intelligenti" in

grado di avvicinare le scelte automatiche con quelle tradizionalmente eseguite dal cartografo nel momento del ridisegno delle carte tradizionali, sia di poter pensare a tools condivisibili e riutilizzabili in contesti applicativi anche differenti, stante la diffusione di modelli dati condivisi tra le differenti regioni e compatibili alle diverse scale.

L'idea di produrre le informazioni territoriali a partire dalle scale di maggior dettaglio, vicino alle realtà comunali che per obbligo normativo gestiscono, coordinano e a volte attuano le modificazioni territoriali, e quindi di ottenere le rappresentazioni di sintesi acquisendo i dati e producendo basi aggiornate non è certo una novità, ma solo in questi anni, con la diffusione di strumentazioni informatiche potenti, ma soprattutto con basi dati già pensate in logiche di sistema informativo, quanto viene ripetuto negli ambienti accademici e di ricerca può trovare reali applicazioni, forse proprio incoraggiate dagli attuali momenti economici che invitano tutti alla sostenibilità degli investimenti.

La presente memoria, a partire dalle esperienze degli autori sulle produzioni cartografiche degli anni 90, riprende in ambiente topologico le procedure di generalizzazione delle basi cartografiche prodotte in ambito IntesaGIS, attraverso originali algoritmi volti alla produzione di elaborati compatibili con le rappresentazioni ordinarie.

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1. INTRODUCTION

Cartographic generalization is the process that allows the creation of maps from an existing one at larger scale.
The reuse of existing data for the production of synthetic outputs, considering both manual redesigning and the semi-automatic or fully automatic processing, returns remarkable cost and time benefits, and have always been used in the production processes of the major mapping agencies and companies that produce base maps for commercial purposes.
The widespread use of digital maps has opened the possibility of automating the process of generalization, a goal that keeps alive intense research in the international context.
The achievement of automatic or semi-automatic generalization would lead to important consequences in the way and timing of maps production, allowing to create, with reduced cost and time, updated map products: under the auspices of the Inspire project, it becomes actually possible to think that the information is collected only once, generally at Municipality level where the territorial transformations are authorized or even carried out, and then proceed to higher synthesis bases, to be employed by hierarchically higher administrative levels.
Many years of research in the field of generalization are leading to increasingly remarkable results: recently there has been a growing interest in automatic generalization techniques in various Bodies and the effective employment of cartographic generalization software in production processes.
The research team of our university has done in the past many experiments, especially in Piemonte region, even from bases not structured as information system, and has developed a series of automated processes for managing the data flow in the generalization process.
The current situation concerning map production at national level, which are increasingly oriented toward standardization, from 2004 IntesaGIS documents to ones contained in the Gazzetta Ufficiale (Official Gazette) no. 48 of February 27, 2012 - S. O. No. 37, in which four Decrees, dated 10 November 2011, were published by the Minister for Public Administration and Innovation in cooperation with the Minister of Environment and Protection of Land and Sea, with which, at completion of the planned regulation in Article 59, paragraph 5 of the Code for Digital Administration, the technical specifications, defined by the Committee for technical data on the territorial government of public Administration, were first adopted.
In particular, concerning these issues, the following documents, available on DigitPA site at the following URL: http://www.digitpa.gov.it/fruibilita-del-dato/dati-territoriali, are to be considered:

- Adoption of the National Geodetic Reference System;
- Technical rules for defining the specific content of the Topographical DB;
- Technical rules for defining the content of the National Directory of spatial data, and the procedure for its setting up and first update.

In this paper, the set of utilities developed, created in ArcGIS environment with procedures developed in Visual Basic, is aimed to map generalization from various scales of input. The outputs are oriented towards metrics or symbolic representations depending on entities types and their respective scales.
The experiments were carried out according to the Topographical DB of Brescia Municipality, produced with the particular specifications developed by Lombardia region and still considered a reference at national level.

2. THE CARTOGRAPHIC GENERALIZATION

The process of cartographic generalization can be identified as a problem of data selection and its abstraction and representation at a generalized scale, on the contrary when deriving from a different map source can be understood rather as a problem of modelling of data from the original map into the output map's model. These two aspects, i.e. representation and modelling, are two features of the generalization with which each project has to cope with.
In addition to the above-mentioned aspects, the development of generalization software should also deal with other issues such as user usability and interaction or computer related issues as performance and computational complexity or data access and manipulation.
Dataset partitioning deserves a separate discussion, which generally becomes significant as the database of origin and destination concerns different cartographic sectors, and therefore pre-designed solutions concerning sectors' edges should be developed.
Specifically, the development of automated procedures in our department has allowed us to evaluate the compatibility between the models, in terms of both semantic and geometric aspects, identifying the feature class as completely derivable, non derivable and those partially differentiable and carrying out the realization of a derivation scheme between the feature classes of the different databases.

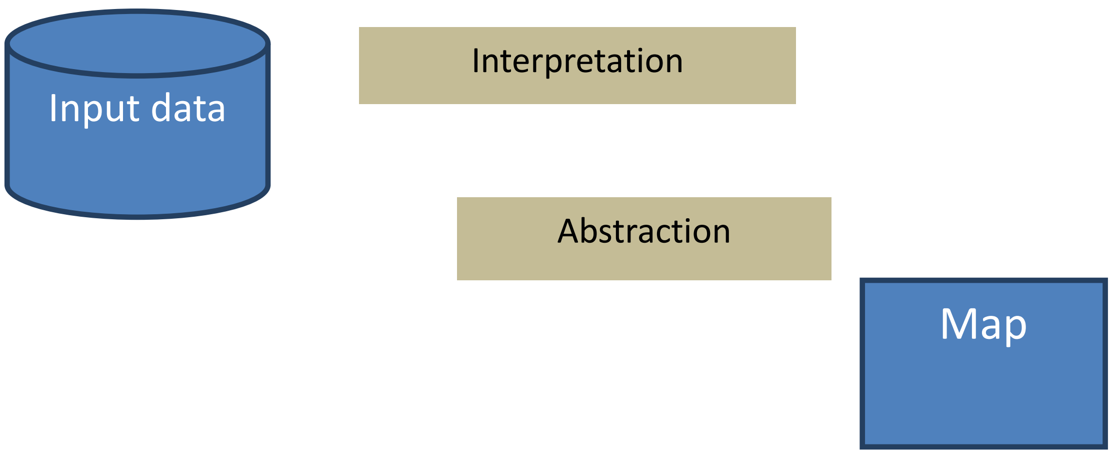

Figure 1. conceptual schema of the process of generalization

The scale shift between the maps scales in medium and large ones requires that most of the feature classes undergo some transformation, that can be as simple as the collapsing of an area to a point, or more complex such as thinning of a group of buildings, and in many cases

requires the development of *ad hoc* techniques for the resolution of each single specific issue.
Except for the simplest feature class, directly derivable, all the feature classes are only partially differentiable, or require some kind of intervention on their geometry.
The semantic generalization requires the analysis, understanding and comparison of two data models in order to find relationships between their feature classes, a complex and delicate task, due of its uniqueness (relationship of the two models are not applicable to other) that is difficult to automate and delegate to a computer.
The generalization of the geometry, on the other hand, is well suited to be automated: a defined strategy of generalization, can be applied automatically to solve all similar problems within the entire dataset; in certain cases the issues of geometric generalization may be enough common to allow that the developed solutions can be used on various scales, feature classes or data models, thus allowing the creation of generalization techniques to be used in different contexts.
For these reasons, while the definition of semantic generalization was carried out using techniques that had little or no automatic; the definition of geometric generalization techniques was carried out by employing available or newly developed algorithms.

3. GENERALIZATION TECHNIQUES

The techniques of generalization have been addressed by many researchers: over the years several models and approaches have been developed.
The first generalization techniques were aimed, as a priority, to the development of algorithms for feature thinning: e.g. from a polyline, the goal was determining an equivalent one, which is described by a smaller number of vertices but retains, as much as possible, the same information content.
Subsequently, with the proliferation of automatic acquisition techniques of (automatic scan, LiDAR, etc.), techniques of extraction of the most relevant content from a database were of fundamental importance: if on one hand the automated tools provide a large number of data, these often are not what an human operator would acquire, and then generates the paradox of having systems with significant processing power that fails under the enormous weight of information.
Generalization techniques employs the results obtained from this transverse research field, developed from advanced statistical techniques which provides a strong optimization approach, but the only geometric thinning can only be a part of the solution.
Great impetus to research has been the use of agent based systems, evolution of an approach that models the generalization according to constraints (CB, constraint-based) and embodied primarily in the European research project “Agent” (2000).
The agent approach, although it is the focus of major generalization software and it is used in cartographic production by some Bodies, however, does not represent the final result of research in the field of generalization, still far from finding a solution to this issue.
The current research trend is the integration of different systems and approaches, with conditional systems and constraints based ones as the main alternative to agent systems.
Our solution begins with a pragmatic approach to the problem, more focused to results achievement that the study of theoretical models: the generalization techniques developed derives from a study of the state of the art, adapting existing solutions to our specific

generalization issue and in other cases by developing innovative solutions.
As previously discussed, the experiments took advantage of the availability, as initial data, of the Topographical DB at 1:1000 and 1:2000 scale, from Brescia, which have been processed in order to produce a derived map at 1:10000 scale, with features compatible with the representation standards at this scale.
We analyze now, in detail, the solutions developed for various data categories.
The generalization of urbanized area is performed by applying complex techniques.
The generalization of each single building concerns the squaring filter which approximates angles next to a right angle to a right one, in order to simplify the building and, additionally, to take into account any of those situations where the squaring filter has not been applied in the production phase.

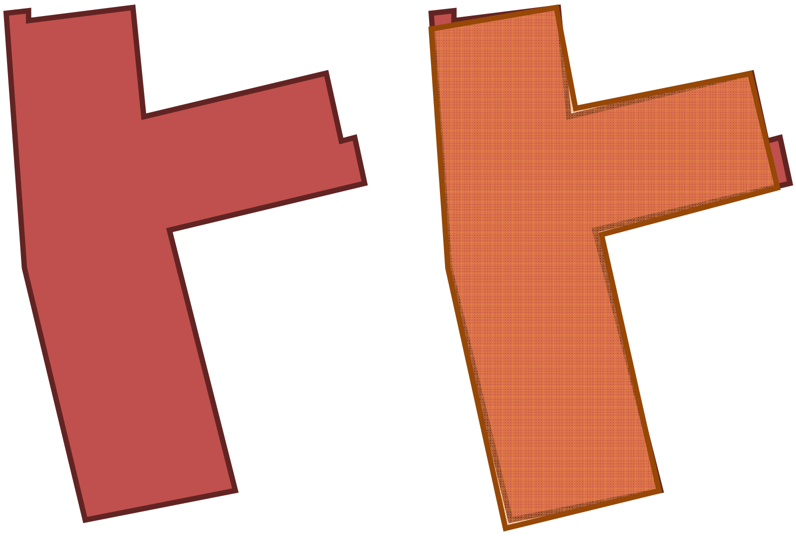

Figure 2: generalisation of buildings

Subsequently, using methodologies established in the literature, using the algorithm of Douglas and Peucker a reduction, in vertices number, is carried out and subsequently the removal of shortest sides.
As in many Italian historical city centers, where the building is not isolated, but they are adjacent to other ones, the process involves the possible merging with neighbouring one within a certain distance. The probable emergence of landlocked polygons is then corrected by topological techniques.

The generalization of road network contains more complex examples of the use of morphological analysis to extract the geometric information not explicitly present in the source data model, but necessary to the process of generalization.
The procedure requires to develop algorithms capable of identifying, within the roadway or highway, the various roadway components, e.g. parking area, junction, ..., which are represented in different ways based on the map characteristics.
The analysis of the graph is used to perform the road network thinning, which is necessary in areas with high urbanization or to eliminate less relevant features. In order to perform this

selection the only semantic data can not be sufficiently detailed, it is therefore necessary to use graph analysis with the purpose of enriching the original classification.
The graph analysis is a technique also employed in the generalization of river network. In a similar way to what has been said for the road network, also the hydrography generalization requires the construction of a taxonomy sufficiently rich to be able to distinguish the less significant watercourses (in relation to the scale of representation) and consequently to carry out the network thinning.
The generalization of fields or, generally, vegetated areas is performed by applying sequential algorithms, according to which areas are combined with similar neighbouring ones, then any clearings smaller than a certain threshold that is generated inside the new polygons are deleted and the edge of the new limit is smoothed by a smoothing operator.
The above mentioned examples show that in some cases the geometry analysis is a key factor for the purposes of semantic generalization, proving to be the only way to extract the necessary information from the original data in order to derive some feature class or some attributes of the target model.
Generally the geometry analysis results as a fundamental part of the entire derivation process, precisely because these features contain information which must be made explicit in order to perform a trustworthy generalization.

4. CARTOGRAPHICAL REPRESENTATION TECHNIQUES

The main goal of this phase is the analysis and testing of methodologies and procedures for the derivation of map representation from Topographical DB contents, by adopting a symbols legend and a representation similar to the traditional medium-scale mapping of Regional Technical Map (CTR).
Fundamental constraints concern the compliance with OGC regulations and the adoption of an approved and shared graphic representation semiotics with the aim of data dissemination through computer procedures.
The approach was oriented to the realization of a dynamic derivation and representation method of Topographical DB objects, derived from the properties of each class, regardless of their spatial structure.
The generated model is compatible with the IntesaGis regulations, and this implies for the data model to be built according to a topology based on the explicit relations between the face’s perimeter edges: the model requires that geometric primitives, related to the spatial components of Topographical DB, are acquired in order to meet specific data organizational needs aimed to an optimization of control processes (query, topology, etc..) that do not necessarily correspond to structuring of elementary geometry functional to symbolic and / or graphic representation.
Therefore the derivation of the representation can not be limited to a simple query on Topographical DB contents, but should also include an adequate reconstruction of geometric primitives with the purpose of map representation.
The solution developed in this paper is intended to enable the automatic updating of cartographic representation as consequence of a Topographical DB object update (instance of a class). Aim of the work was therefore the processing of representation algorithms implemented in accordance with the OGC regulations, particularly Styled Layer Descriptor

specifications (OGC SLD, 2007) and Symbology Enconding (OGC SE, 2006).

The most critical phase in the realization of a cartographic representation, derived from a Topographical DB, consists in organizing geometric primitives of spatial components with the goal of producing symbolizations meeting the criteria of representation, despite the segmentation of the geometry meets database criteria and not representation ones.
A second critical aspect of the methodology concerns the link between content structure and representation one in Topographical DB, thus an object update in Topographical DB should trigger an automatic update of the associated representation.

5. CONCLUSIONS

The automatic cartographic generalization is a very complex subject and the development of generalization techniques must also deal with aspects linked to the semantics of the geometry data to generalize. The examples and techniques presented in this paper highlight that the information needed to perform a reliable generalization is contained implicitly in the geometric data to be generalized. Designing algorithms that can extract this implicit information and interpret it in a similar way to what, unconsciously, the operator do while creating or using a map, represents the biggest challenge of the automatic generalization, a challenge that despite the continuous advances is still in progress.
The potential impact of automatic cartographic generalization, however, offers such clear advantages, both in production and maintenance of map products, to justify continued research in this field.
The development of techniques for automatic cartographic generalization, although complex, is a very important opportunity, and a necessity in some ways, to streamline and modernize the national cartography system, and not only in Italy, an opportunity on which it is important continue to invest and cooperate in order to better exploit the advantages that this technique can offer.

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