3D CARTOGRAPHIC DATA COLLECTION FOR GIS ENVIRONMENTS

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ABSTRACT

Technical possibilities in digital cartography seem to have compensated a lot of inherent limits connected to traditional mapmaking process. Digital cartography constitutes the reference for real elements and phenomena representations, as well as it acts as an interface for heterogeneous geographical data (raster and vector) integration in GIS environments. It works as windows that connect users with a geo-database, since it permits manipulation of the contents as well as of the structure of the GIS systems.

Today there is an increasing demand for 2.5D and 3D geospatial information. The major 3D progress is observed in the area of data presentation. All traditional GIS vendors provide extended tools for 3D navigation, animation and exploration. However, still many of these systems are lacking full 3D geometric and topologic models.

Considering the above outlined problems, the present study analyses problems arising with 3D cartographic data collection, in order to permit spatial analysis in GIS environments and dissemination with web technology.

1. INTRODUCTION

Innovations introduced in geographic information, such as GIS, GPS instruments, VHR satellite imagery and global advances in IT, nowadays allow data availability and sharing which are indispensable tools for economic and social development and resources conservation in wider and wider territories.

2. NUMERIC CARTOGRAPHY

Traditional maps are abstractions of the real world, a sampling of important elements portrayed on a sheet of paper with symbols to represent physical objects. People who use maps must interpret these symbols. GIS technology, as an expansion of cartographic science, has enhanced the efficiency and analytic power of traditional mapping.

Not long ago, in Numeric Cartography the primary product was cartographic representation, even if it was based on a Database. The object structuring was executed in conformity with legend classification.

Figure 1. An example of Italian Numeric Cartography
The subdivision between “base” and “thematic” data was usually made according to specific requirements of customers. Particularly, “class theme” regards not direct acquisition but consists of a next interpretative processing. For the above reason all the same fundamental information, for example cadastral ones, are not directly inserted in reference databases, even if their next important integration is pointed out and can be realized without particular data restructuring.

The starting point for the contents definition is constituted by what is nowadays reported in the specifications of Technical Cartography, from local and regional Territory Management Institutions, and also derived from comparative analysis. The information content of such specifications, based on photogrammetric stereo-plotting and on site ascertainment, must be integrated with opportune adjustments in order to be suitable for database efficiency as support for GIS utilization, although this will imply an increase of costs. In time both Numeric Cartography and GIS environments evolved in products which are similar for many aspects:

- object identification, for instance roads area, with the consequent insertion of fictitious closed lines where buildings do not exist;
- topologic consistency among objects and particularly borders sharing;
- unique object ID, in order to guarantee relations with external archives;
- structure as database and continuous content updating, in order to maintain connection with internal information system archives.

3. GIS AND TOPOLOGICAL INFORMATION

GIS can be considered as database systems that combine data sets of different types from different sources about different features/objects. They contain both geometry data (topological information) and attribute data, i.e. information describing the properties of geometrical spatial objects such as points, lines and areas.

In order to collect cartographic features for territorial information management through GIS, priority requisites have to be respected. Features/objects structure can share next proprieties:

- each territorial object has to be defined completely by a closed polyline. In particular, in the case of its shape, dimension and position in the geographic space which are defined by the spatial component of the object itself (coordinates and quote);
- each class of objects has to be represented not by a code alone but by more attributes;
- the objects acquired should guarantee a planimetric covering of the area, that is to say each portion of the territory has to be opportunely classified, avoiding both superimpositions and gaps.
- each class should be depicted by a unite description, apart from the acquisition and/or presentation scales, making thus explicit the detail differences due to the different thresholds of acquisition.

In particular, the constraints which concern the spatial properties of objects should express the topological relationships, the accuracy and the shape.

Spatial processing requires the predisposition of a topological structure on the whole of data. The topological correctness, sharing included, has to be fulfilled in the spatial components of objects, according to the conceptual models or other constraints declared explicitly. Topological consistencies which require the closing of outlines or the convergence of lines at the same top are to be respected. This operation is rather easy to fulfil by a relative control of each cartographic element to be realized.

4. THE THIRD DIMENSION

Computer-generated 3D images are a relatively recent phenomenon utilized in many application fields. Low platform costs, higher performance, and better software applications have brought the technology within the reach of many organizations (Levy, 1995). 3D visualization is one of the most natural ways to communicate. The public understands these scenes and buildings intuitively, without any knowledge of cartography or having to decipher map symbols because 3D visualization closely imitate a real life experience of the built environment (Masum et al., 2003).

Along with the development of computer technique, especially in 3D graphics and visualization, the people have ability and deeply wish to increase 3D function in 2D GIS system in order to realize 3D display, manipulation and analysis for more and more application requirements. Also, 3D modelling and visualization are important techniques of Digital Earth which is presented in recent years (Qingquan, Wenzhong, Bisheng, 1999).

Spatial data contains positional values and the attributes describe what the data is and eventually the information of objects and their surrounding through spatial analysis operations. We would not be able to understand the objects fully if the analytical operations were not done in 3D space as we perceived in the real world (Rahman et al, 2002; Zlatanova et al., 2002).

The difficulties in realising 3D GIS or 3D geo-spatial systems result from:

- Conceptual model: although there are several data structures available for the 2.5D and 3D data, each of them has its own strong and weak points in representing spatial objects.
Spatial data can be modelled in different ways. The conceptual 3D model integrates information about semantics, 3D geometry and 3D spatial relationships (3D topology). The conceptual model provides the methods for describing real-world objects and spatial relationships between them. The design of a conceptual model is a subject of intensive investigations and several 3D models have already been reported.

- **Data collection**: Modelling in 3D drastically increases the cost of data acquisition, as compared with 2D. Despite the progress in automatic object detection and 3D reconstruction, the manual work is still predominant. Methods for constructing the model combining data from various sources, automatic techniques for data acquisition (geometry and images for texturing), rules and algorithms for ensuring consistency of data, algorithms for the automatic building of 3D topology, etc., are the widely discussed topics in the literature.

- **Spatial analysis**: Whilst thematic analysis and 2D spatial analysis are well studied, research on 3D spatial analysis is still at an intensive stage. Spatial relationships are the fundament of a large group of operations to be performed in GIS, e.g. inclusion, adjacency, equality, direction, intersection, connectivity, and their appropriate description and maintenance is inevitable. Similar to 2D variants, 3D GIS should be capable to perform metric (distance, length, area, volume, etc), logic (intersection, union, difference), generalisation, buffering, network (shortest way) and merging operations. Except metric operations, most of them require knowledge about spatial relationships.

- **Visualisation, navigation and user interface**: Advances in the area of computer graphics have made visual media a major ingredient of the current interface and it is likely that graphics will play a dominant role in the communication and interaction with computers in the future. 3D visualisation within 3D GIS requires a number of specific issues to be investigated, e.g. appropriate means to visualise 3D spatial analysis result, tools to effortlessly explore and navigate through large models in real time, and texture the geometry. Observations on the demand for 3D City models (see Gruber et al 1995) show user preferences for photo-true texturing, due to improved model performance in terms of detail and orientation. Trading photo-true texture raises new topics for research, i.e. collection (methods, automation), storage (original images vs. separate pieces) and mapping onto the "geometry". Specific functions of objects modelled in VR systems, and referred to as behaviours, gain an increased popularity as tools for walking through the model, exploring particular phenomena and improving the cognitive perception.

- **Internet access**: Remote access to 3D spatial information is one of the newest research topics. The Web has already shown a great potential in improving accessibility to 2D spatial information (raster or vector maps) hosted in different computer systems over the Internet. New Web standard (VRML, DML) have created the ability to distribute and navigate in 3D virtual worlds. The research on spatial query and 3D visualisation over the Web has resulted in a few prototype systems. The design criteria, however, are visualisation rather than spatial analysis-oriented (Rahman et al, 2001).

Whereas the third dimension constitutes a necessary characterization of system, we need rules like the following ones:

- the quoted outline of the corresponding planimetric area which forms the outline of the “ground parting points” should be acquired from each object;
- the consistency of the three-dimensional outlines and the inherent properties of objects, as uniqueness of the quote of the building covers, should be guaranteed;
- DTM should be consistent with the objects present in the Data-Base. In fact, DTM should be made by taking into account the three-dimensional outline of all the objects which are in the Data-Base. Consequently, the DTM of the urbanized area will turn out from the context of the outline lines of objects and, also, from the whole quoted points;

In order to be consistent with the outline of all the objects, DTM should be defined by a TIN structure.

![Figure 2. Incorrect identification of elevation](image)
Without precise specifications on three-dimensional at best worst Numeric Cartography produces models with city blocks. In the plotting phase the borders of such 3D polygons are principally considered, instead of single buildings identification. In the next Figure 5-6 is shown the difference between blocks and buildings representations.
Figure 6. Single buildings identification

A completely 3D approach in GIS environment should produce different results. In the next Figures 7-8-9 current cartographic data collection and possible desirable 3D model of building features are shown, also linked database with street numbers, floor numbers, etc.

Figure 7. 3D model of cartographic features

Figure 8. 3D model of building features
An other analysis should be made on feature elements regarding transportation field in GIS. In order to guarantee graphs compatibility with this last application (for example Roads Cadastre) GDF standards (CEN TC 278, ISO /TC 204, ISO /TC 211) as reference are considered, by adopting only specifications on spatial and topological structure of graphs. It should be desirable to remark the information on quota. For example, for a underpass also the third dimension has to be inherited in bidimensional component obtained with planimetric projection.

5. CONCLUSION

Geographic Information should be recognized as forming part of infrastructural resources which are necessary to the economic development of a territorial context (e-infrastructure).
On a European level a similar infrastructure, the ESDI of INSPIRE, has been realized in order to fulfil the few existing specifications. The primary importance is the suitably investment in the sector, in order to face the exigencies of technological development required by the economic one to fill the current thick inadequacy. The approval of “INSPIRE” project by European Commission has stressed the need of an Italian infrastructure (such as the one foreseen by the European project for the NSDI) and specified how this infrastructure should be realized by a very efficient logic for a real “service”.
Such approval confirms how a national intervention in the sector is urgent and how the infrastructure of the spatial information is vital to the development of a territory and, above all, to the choices to be made in a time limit.
The experimentation of a proposal of regulations which could consider problems and cases described in this study should allow the control of each aspect of several problems not only in a prototype context of a wide survey. Moreover, it should involve the experience of all operators of the sector, from users till the world of research, the suppliers of cartography and GIS.
Experience will have to consider the following criteria:
- the availability of Topographic Data Base,
  its adequacy against the dissimilar uses with whom it has to integrate, that is to say the direct usability of its contents and above all the adequacy to be integrated into the several data bases of the applications of the sector; which is its effective potentiality in the constitution of a first shared base which could be the assumption for a wider operation of integration and sharing among data bases.
- the effective grade of interoperability,
  which can be established among the different Authorities and Offices as a verification of the assumption of the whole project. What are the modalities, the rules ed efficiency, what is the real distribution and subdivision among the authorities and the territory, in the national operative context.
- integration of an Office or Authority in the Informativ System,
  which are the problems and the optimal solutions in the project and fulfillment of its own Database, of its own context of spatial elaboration and of management of territorial information (GIS); which are the problems and the solutions for an efficient web sharing and by which technologies.
Moreover it is necessary to deepen which frontiers to establish for the third dimension against the new technologies such as LIDAR and against the functions of elaboration of the same and of the emerging news of the sector.
A coordinated effort towards this direction will allow all the national context to place itself into a European one and, moreover, to face up the new emerging and urgent demands in the field of territorial data elaboration, providing thus with what seems to be a fundamental infrastructure for the management and development of territory.
References


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Biography

Mauro Caprioli is Full Professor in "Topography and Cartography" at the Department of Roads and Transportation of the Polytechnic of Bari, in which he is also Responsible for the "Topography and Cartography" Laboratory. From 1997 he is President of the Degree Course in Engineering of Infrastructures, Polytechnic of Bari.
He is advisor of Public Administrations for the provision of Standards and Norms in the field of Digital Cartography and Geographic Information Systems, the execution of Cartography and Civil Engineering Great Works. tests and controls.
He is President of Bari section of S.I.F.E.T. - Italian Society of Photogrammetry and Topography, of which he is fellow of the National Directive.
He is Fellow of A.I.T. Italian Association of Remote Sensing.
He is Fellow of the editorial board of the national scientific journal Bollettino SIFET.

The scientific activity, testified from over 80 publications on national and international conferences and journals, has essentially been turned to the sectors: deformations control and monitoring, geodetic and navigational GPS, geodesy, treatment of the observations, applied photogrammetry, cartography, GIS and remote sensing.