A STEP TOWARD INTEROPERABILITY: MANAGING 3D URBAN DATA WITH GML STRUCTURE

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ABSTRACT

This paper describes the phases of the development of an experimental structure of numerical cartography, at medium and large scale, to be used in GIS and to be proposed as a national standard.

Today needs for using cartography in GIS applications require the allocation of 3D data; besides, data must be fully topologically structured. So in order to define a new model of numerical cartography, it's necessary to apply new cartography models also implemented into a format as GML that should grant interoperability.

At present, GIS software have no advanced functions to easily handle 3D objects and respective spatial processing, like geoprocessing, using 3D spatial relationships; moreover 3D information is exchanged by formats not proper for GIS use, like CAD or DXF formats, or using the GML 3.

According to the main goal, research has been organized into four steps:

- the first, deals with importing, managing and extracting DXF data in a CAD environment as preliminary operation to interoperability tests inside GIS software;
- the second deals with the problem of managing and sharing geographical information written in GML between the most diffused GIS software on the market;
- the third consists in the analysis of some models for numerical cartography, both national and international too;
- the fourth is represented by a proposal for structuring cartography and application tests on this model.

So on the basis of tests carried out using different software, specifically looking to handling 3D information and data interoperability, it is possible to say that GML format is potentially suitable to structure numerical cartography in order to interchange it also for a traditional use, but it's not fully suitable to be used as data format for a dynamic read-write access; at last coding requirements of geographical information has been made clear, laying the bases for a 3D cartographic model structured in GML.

INTRODUCTION

During last years, research activities on the procedures to structure and to exchange geographical data has been carried out in the GIS laboratory at Dipartimento di Rappresentazione of the University of Palermo; particularly, geographical data containing 3D information has been studied and analyzed. Studies began from the use of DXF coded data (specific of CAD systems) in order to import 3D data in GIS software; through GML format, that constitutes a step toward interoperability and a support for advanced characteristics of geographical data, a cartographic model has been defined and it's under development. In spite of these advanced characteristics of the format, at present the most used commercial GIS software are not ready to manage GML3.

CARTOGRAPHY'S REQUIREMENTS

Today numerical cartography must satisfy a large number of purposes and it has to be provided with specific characteristics to be suitable for certain uses.
The main characteristic of cartography is the nominal scale, which is related to printability, topology support, generalization (from a great scale to a smaller one), 3D support, LBS support.
Obviously the first feature, an advanced numerical cartography must have, is that it can be used like a traditional analogical cartography (printable cartography). To reach this aim, a common graphic style has to be defined using, for example, an only graphical stile sheet.
Another important characteristic of numerical cartography is the presence of third dimension useful both for visualization and analysis, for geoprocessing and computation (like volume calculation, visibility charts, cost's evaluation, etc.).
The generalization of cartography represents an ulterior challenge in building cartography. We distinguish two types of generalization, called “first level” and “second level”: the first one consists in grouping information pertaining to a certain scale, the second implies that original data have to be processed so to obtain a different data, consistent with the smaller scale both for geometrical information e for attributes. This second type of generalization beyond the strictly geometrical problem, reveals another bigger one, that is the respect of topological rules during processing data.
In addition to the above, complying with topological rules can't be considered as optional, because data that aren't topologically structured cannot be used or processed in advanced application such above mentioned; for example, calculate a route on a graph could be impossible or very difficult without topological rules.
At last, we consider that a model of cartography should not be oriented only to the visualization, but to the management of urban transformations and the management of ownership too.

TESTS ON DIFFERENT SOFTWARE

Sharing different kinds of information, and among them spatial data, put the question of construction of a cartographic model to build and manage geographical information at large, medium and small scale. So it becomes necessary to solve many problems concerning the use of different GIS instruments by customers, the definition of an appropriate format for exchanging and transferring of geographic data, the design of a common cartographic model. In order to reach this aim, 3D component, geometrical exactness and topological consistency of data (especially for areas) are very important matters. Cartography, also when it’s to be used in GIS, is generally produced by CAD systems and provided in CAD formats or as a shape file; besides the topological content is present only if the data come from professional GIS software (i.e. ArcInfo).
All this involves verifying which information keeps connected to an object class when a file, in one of these format, is loaded into a GIS software. The research group has carried out many tests above the most diffused GIS software (Geomedia Professional, AutodeskMap 3D,

MapInfo, ArcInfo, Grass), with the aim to examine how each of these software handles geometric attributes and topological relationships.
Starting dataset has been drawn up using Autocad 2005 in DXF format, and it is made up by 3D elements (faces, open and closed polylines, points). Each different software, reading (Autodesk Map 3D, ArcGIS, Geomedia) or importing (MapInfo, GRASS) the same DXF file, performs in different ways, and sometimes it can't correctly identify geometry and topological relationships. Besides two objects having seemingly the same geometry, but one made with a face and the other with a polygon, are often differently detected by the same software. It implies, for example, that some nodes of these objects are identified as vertices: the consequence is a different attribution of the elevation, that is always identified as the elevation of the first vertex. Regarding object's topology, it comes out that points, lines and polylines are correctly handled by every software and so "cleaning" and "building topology" functions can be applied; beside surfaces in 3D space generally are ideally projected on a plane, and also the calculated area is actually that of the projection.
The use of GML allows to standardize the methods to describe geographical objects and to make easy the interoperability. Generally every GML file is combined to a schema file with a structure referring to the rules defined by *Open Geospatial Consortium.*
The specifications allow a wide range of freedom; for example in the definition of not mandatory attributes, it may happen that objects of the same type, defined by different GIS software, are characterized by a different structure.
The different tested software generally supports version 2 of GML; only Geomedia Professional also supports versions 3.0 and 3.1, that were used as experimentation subject.
A dataset (the same used for the tests executed on DXF file) was exported in the GML format version 2.0, and then, as a second step, it was imported within the tested software, in order to evaluate the possible loss of information. Then it was executed the exportation of the file just imported. Besides, to verify the innovation introduced by version 3 of GML, some tests have been carried out using another dataset.
After these tests, that were a preliminary operation aimed at evaluation of GML handling by main GIS software, the main cartographic models, both national and international, have been evaluated. Final result of this part of the work is to underline some lacks, for our purposes, found in these models, and then to propose an enhanced cartographic model designed to be used in map-making activities too.

THE "INTESA GIS" MODEL

The "Intesa GIS" (Intesa Stato Regioni Enti-Locali) model is a cartographic model built by an italian working group composed of several members of the main public italian bodies.
Main features of the model are reported below:

- geometrical schema is based on the ISO-19107 standard, that includes solids; notwithstanding this, not every classes of the ISO-19107 standard are adopted, to easily distinguish between 2D and 3D features and to make easier the use of this model by unskilled users;
- generally it's impossible to directly define objects with three dimensions, or volumes;
- surface are represented in two dimensions only, but there is an "hybrid" way to model 3D surfaces, using a class of spatial attribute called "B3D surface", that is constituted by a 2D surfaces joined with a 3D ring that is the boundary of the surface;
- topological constraints are defined separately from the geometry;
- compound, complex and aggregate objects are defined;
- level of detail are not defined, because geometrical information is frequently and strictly

linked to the scale of the representation;

This cartographic model is not fully oriented to 3D visualization and analysis, that represent important feature to accomplish typical GIS operations.

THE "CITYGML" MODEL

The "CityGML" model is a very interesting cartographic model, mainly oriented to structure 3D models of cities, carried out by a consortium of several German bodies, both public and private. It is an application profile for GML3 which encodes a multi-level representation of cities, also including elevation, vegetation, water bodies, city furniture and more. The most important among its characteristics are:

- the use of Level of Detail, that point to solve one big problem on structuring cartography, or using cartography at different scale and with different contents;
- only one geometric-topological structure.

Besides CityGML introduces textures into GML, to make more realistic models.

OUR PROPOSAL

Some cartographic models have been examined, and hence a cartographic schema has been developed, mainly moving from *CityGML* model and *Intesa-GIS* model.

In order to allow advanced use of cartography in GIS and WEB-GIS world, the aim of this model is an attempt to put together the requirement of respecting well-established rules (i.e. the ones coming from *Commissione Geodetica Italiana*) regarding a shared way of structuring entities of numerical cartography, and the need of three-dimensional visualization and analysis of urban and out-of-town landscape.

Main features of this model are:

- structure according to indication of rules coming from OGC and ISO 19100 series;
- topological constraints defined together with the geometry;
- aggregate objects not defined;
- geometry structured using nodes and lines as primitives ;
- various feature classes geometrically described using *curve 2D*, *ring 3D, surface 2D*, *face*

3D node

The definition of main classes has been carried out according both to geometrical aspects and thematic too; so defined structure goes beyond the classic one often used in Italy, founded inside the recommendations of *Commissione Geodetica Italiana* and strictly based on layers. Feature class are grouped and linked into a schema that is split in different smaller schemas, depending on the main classes that are described as follows:

- *vegetation*: parks and gardens, rows of plants, single plants;
- *network infrastructure*: networks and pipelines for carrying water, gas, electricity, etc.;
- *orography*: isohypses, spot heights, breaklines, natural shape;
- *hydrography*: rivers, lakes, sources;
- *transportation infrastructure*: roads, railways, undergrounds and their accessories (parking and depot areas, pavements, road axes, etc.);
- *building*: edifices and their accessories, set of buildings, other buildings (i.e. pylon, walls, etc.).

The *'Building'* UML diagram, still under development, is shown below (Fig. 1).

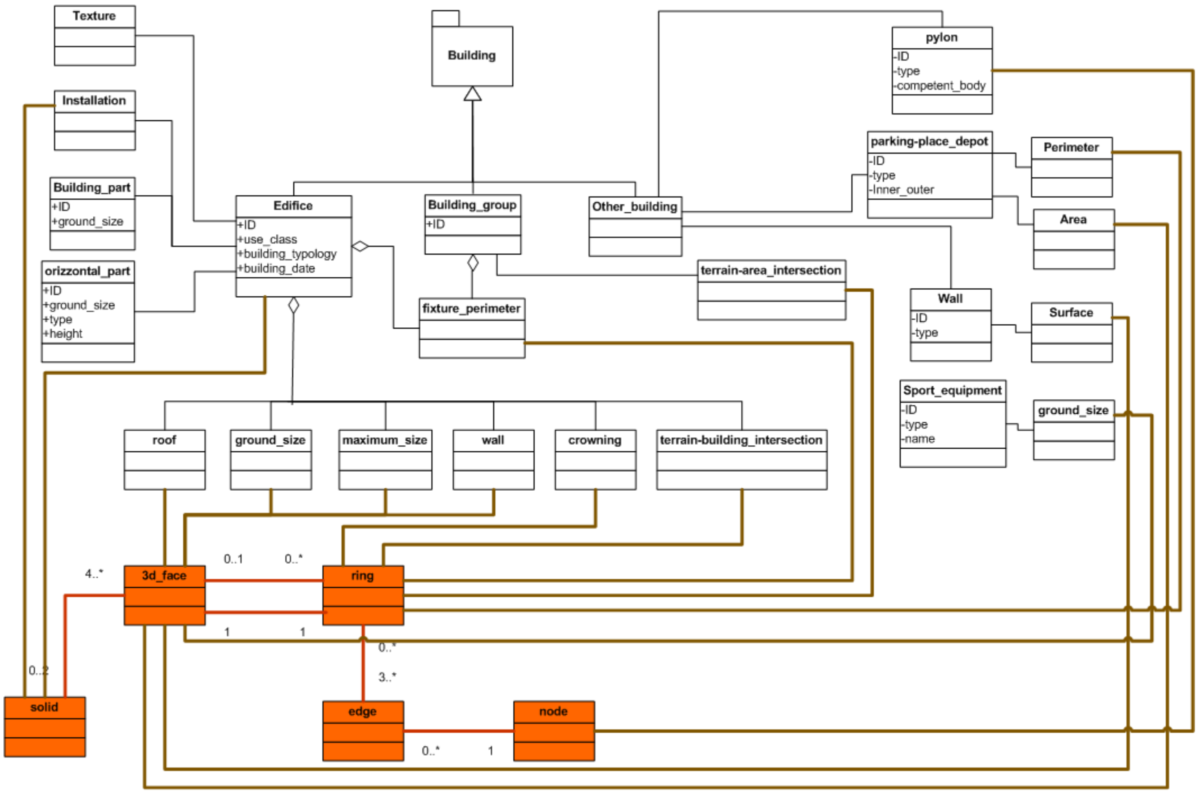

Figure 1: UML diagram of building.

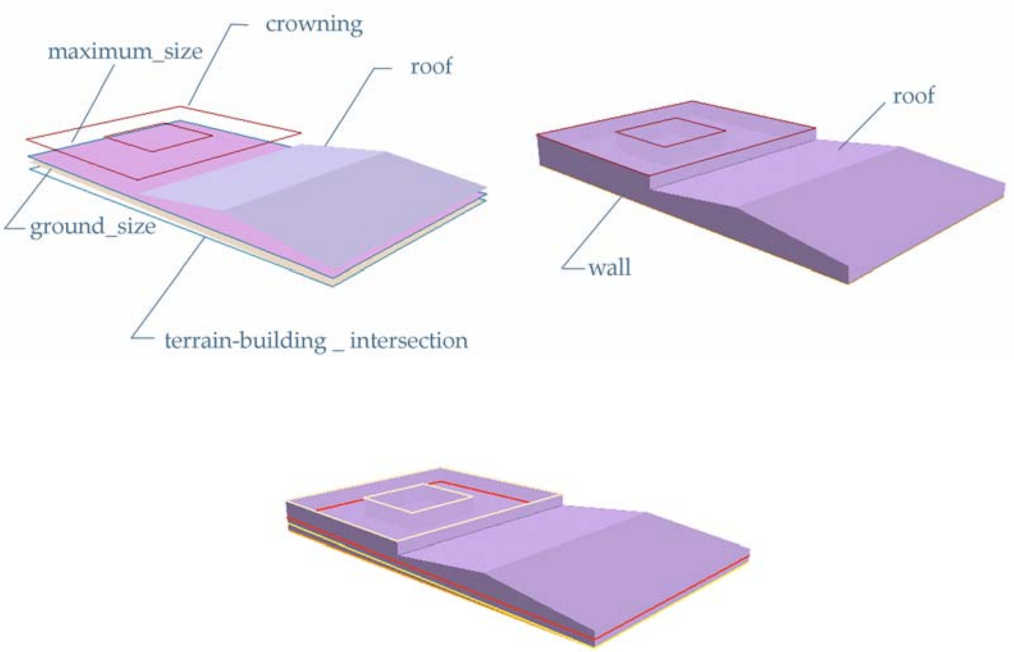

Figure 2: Components of an edifice.

In the schema each element of the class has been connected with the geometric-topological reference object. The exemplification of the 'Edifice' class is shown in the Fig. 2: an edifice is described both with 3Dfaces (which define a volume) and with lines and planar surfaces that define its significant parts.
At this time no Level of Detail, as intended in *CityGML* model, have been implemented due to the difficulties to be actually carried out. Our model is designed to be consistent with a scale from 1:5000 to 1:2000, but it's necessary to introduce more detailed zones (intended at a scale 1:1000 – 1:500), regarding public utilities and services, like hospitals, theatres, university's campus, municipalities, and so on.

CONCLUSIONS

Data are built and edited in Autocad Map environment at this time; the choice of using this software is due to its powerful editing tools, as well as 3D visualization capabilities.
As soon as the model will be fully defined, to reach the aim proposed two main problems must be solved:
1) after data have been correctly geometrically structured, it's necessary to allocate attributes and to assign each entity to various feature classes;
2) find the way to export data in GML format, using an appropriate schema file, without using predefined software tools;

To solve the two main problems mentioned above a software module, able to correctly topologically and geometrically structure cartography, is under development; its main characteristics will be:
- to assign a feature (usually a line or a polyline) to a single or a multiple class;
- to assign attributes of each feature in the inner database;
- to export structured data in GML 3 format.

Software is currently under development in a Visual Basic Environment as Autocad Application.

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