

Intelligent Models and Ideal Cities: a Data Model for a Sustainable Urban Planning and Cultural Heritage Safeguard

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Abstract. The problem of the safeguard of cultural heritage in Italy has always been a complex and debated question. On the one hand, the urban development and its planning come into conflict with the needs of preserving cultural-historical evidence; on the other, preserving plans that are not discussed within the growing exigencies of modern urban centers risk to generate new fractures between the “city of the past” and the “city of the present”.

Keywords: data model, UML, Object Oriented Programming, GIS, cultural heritage safeguard, urban planning

1. Introduction

With this work we intend to emphasize the need of making archaeology ‘grow up’, putting it to the service of local urban communities and town councils. We thought this work as directed to all the institutions that manage and protect the cultural heritage, as well as regional administrations, provincial administrations, town councils and private companies that interact with the archaeological field activity. Our investigation tends to a new developing field that we could define “intelligent GIS solutions”, in which the building of a data model is the main topic of the system, the CASE (Computer Aided Software Engineering) tools assist the design process by helping to automate the development of various UML diagrams used during the design process, and the design model is a blueprint for the database scheme, for designing classes and classes extensions with custom behaviour. The aim of the data model here exposed is not to define semantic and conceptual standards; we tend to develop tools with prevision functions regarding interactions among spatial-geographical features related to modern infrastructures and archaeological evidences. Moreover, the problems of fixing unique standards for the archaeological scenario is not only connected to different methodologies or different schools of thought that, as years go by, have elaborated many reference models often creating conceptual and terminological confusion, but it comes from the absence of legislative indications about the problems of “archaeological sensitivity” and respect areas defined in accordance with regulative and unspecified reference parameters. Therefore this work looks as an instrument of dialogue between cultural heritage management administrations and utilities companies.

2. Data Model as a Tool for Data Standardization

Few years ago the standard idea of a geographical information system data model was ascribed to the definition of file formats

able to assure data export. Nowadays, thanks to the availability of object-oriented data modelling, it is possible to elaborate standards involving the definition of accepted procedures in order to structure and normalize complex data.

If, on the one hand, we notice the proper need of implementing a data model based on the observation that “physical reality” is too complex to be represented and managed in a simple way by a Geographical Information System without an adaptation process named ‘discretizzazione’ (D’Andrea 2001:337), on the other hand the firm attempt to determine common describing protocols, if lacking in awareness that this operation could represent the core of GIS building process, risks to take the research of a codifying method of data too extreme: it could produce rigid categories that will not succeed in outlining the peculiar variables related with the interaction between humans and landscape. From this point of view, the procedure that allows us to describe real world through a model, condensing reality and revising it into classes and attributes, could be a priori conditioned by the ideology of the Author and his/her school of thought (Hodder and Orton 1976, Clarke 1977, Flannery 1976, Welinder 1975, Bakels 1978). The result could be the introduction of new variables unrelated to the context that has to be modelled. It is therefore extremely difficult to create standards related to anthropic components.

An operative step that, in our opinion, could make the building of a data model based on past societies behavioural variables easier is, during the data model creation process, the organization of reality in two essential components: one that describes the physical variables of the context (a shape, a perimeter, an area), and one that describes the ideological traces of those human variables that modified the territory and their functions at the moment of their conceiving and realization.

As we said, it is hard to sum up the variables related to human behaviour in rigid tables of attributes: most of all, because these are subject to the interpretation of who creates the model. Debating about data model “strictu senso” could prefigure the outlining of a complex conceptual condition. It is reasonable to remember that the data model is relative and it’s connected to the function for which it is planned.

3. The archaeological data model

To start with the discussion of data modelling it is important to recall that the model, according to system science, is the “representation of reality”, which selectively expresses certain relevant characteristics of the observed reality, and consists of objects or systems that exist, have existed or may exist. As a representation or an abstraction of the observed reality, a model is always a simplification of the complexity of reality, making such reality more understandable and operational (Crowther and Echenique 1972, Putra 2003). A data model is an abstraction of the real world that employs a set of data objects that support map display, query, editing and analysis (Zeiler 1999, Putra 2003). We planned our GIS data model, as a bridge between archaeological reality and its spatial representation in GIS. Data modelling represents the core process in building our GIS system; it consists of three levels of prototypes concerning Geodatabase creation: the conceptual, the logical and the physical model. The conceptual model coincides with the upper level of database block diagram. The logical model is a detailed layout that completes the conceptual scheme in accordance with a specific data model. The procedure includes the definition of the database content (its spatial properties, its attributes, its behaviours), the selection of specific geographic datasets and the organization of the content in thematic areas. The physical model corresponds to the creation of the final layout of each geographic dataset and independent table. During this phase we could decide how to record the data and which are the codifying schemes to use; it is possible to determinate the keys and the relations, to define domains and subtypes and a convention to standardize names of spatial data, attributes and relative files. At last we decide which informations we could use as database documentation and which procedures will develop it. This phase is a detailed transposition of a conceptual design in a physical layout.

4. The Conceptual Model

The phase that concerns the conceptual model has regarded the identification of concepts, improving them into classes, and the identification of attributes and associations that have composed the database schema. During the designing phase of our model, classes have been structured correspondent to the Geodatabase feature classes and for each class have been fixed specific attributes and relations. In this phase each and every element of the model has been documented and detailed (names, field-attribute types, attribute properties, relation names, cardinalities). All through the design, starting from the logical and going to the physical model, we have used Microsoft Visio. This application makes it possible to develop a data model using UML language. UML is a visual language suited for Systems design. In GIS application Visio is used to design databases, in this context, geographic databases or geodatabases, the new ESRI geographic data model. Visio simplifies design process using a visual technique. ESRI adds geographic functions to UML, allowing this language to design a geodatabase data model. Stereotype and tagged value

transform simple UML classes into feature classes, relationships into geodatabase relationships, and so on. Following the work procedure described above we have identified three chronological areas: prehistoric, roman and medieval. Inside each area it has been created an abstract super class, named archaeological. It consists of a general class defined by normative and descriptive attributes (toponym, extension, orientation, constraint, respect area, description, chronology and interpretation). Through the relation named generalization (classifying relation among general elements and specific elements), many leaf classes are connected to the super class. These leaf classes coincide with tables and feature classes that are going to be recorded inside the Geodatabase and, as a consequence, with the archaeological objects examined in this work. Leaf classes differ on the basis of chronological phases. When we finished to design our data model we checked it against syntax and semantic rules. Then we exported it into an intermediate format, which can be imported by ArcCatalog. Visio 2002 can export in Microsoft Access Repository or in XMI files; in our project we chose XMI export. In order to physically implement our model, we imported this file using ArcCatalog Schema Wizard.

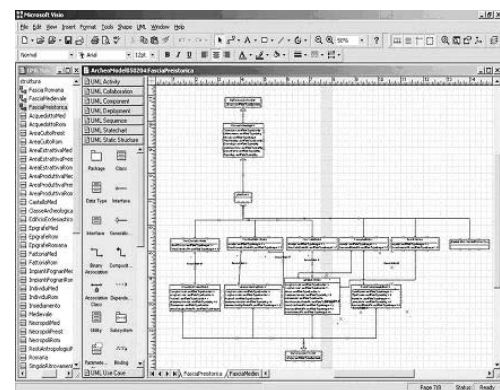


Fig. 1. Prehistoric diagram, realized with Visio.

5. The ArcGIS Software

Every product of ArcGIS suite includes three main applications: ArcCatalog, ArcMap and ArcToolbox. ArcCatalog is the application dedicated to the data-managing scheme. In ArcCatalog it is possible to create new Geodatabases, Feature datasets and feature classes. In ArcCatalog it is possible to design attributes of feature classes, choosing data type and domains. This is also the application where it is possible to add intelligence to data model designing relationships, network topology and polygon topology. This is a useful application for simple test geodatabase or standalone application. ArcInfo 8 introduces a new object-oriented data model called the Geodatabase data model. The defining purpose of this new data model is to let you make the features in GIS datasets smarter by endowing them with natural behaviors, and to allow any sort of relationship to be defined among features. Some of the benefits of the geodatabase data model are that: a uniform repository of geographic data is created, data entry and editing is more accurate, users work with more intuitive

data objects, features have a richer context, better maps can be made and many users can edit geographic data simultaneously. A principal advantage of the geodatabase data model is that it includes a framework to make it as easy as possible to create intelligent features that mimic the interactions and behaviours of real world objects.

6. From the Model to the Intelligent Planning

After having transferred the Geodatabase into ArcCatalog we moved to the ArcMap cartographic editing tool. ArcMap is the core application in ArcGIS Desktop. This GIS application is used in every cartographic operation, from production to analysis or editing. This application has allowed us to manage the cartographic part acquired into the GIS system: it corresponds to an urban neighbourhood during an expansion phase. In this operative step a water service network has been reproduced (it is a part of the data model) and the archaeological evidence has been positioned, preserving cartographic differences through a qualitative thematic representation that visualizes each element in a unique symbol; this will allow the creation of a ‘table of contents’ that will be used to identify the different typologies of evidences. The background of our case study includes two different situations: the first one is a situation where new blocks of houses are established and a need to be connected to the main water service network, the one is a situation with established blocks, where archaeological surveys and excavations have never been carried out, and a new water service network must be installed. An archaeological respect area will be designed with a buffer and, over it, a water pipe-laying will be drawn. During the planning phase of the water service some topological rules will be fixed in the Geodatabase using ArcCatalog; these will show on ArcMap all the editing mistakes using graphic features, polygonal geometries, that will identify the topological mistake positions. Thanks to the Error Inspector, a tool set on ArcMap Topology Bar, the opening of a dialog window will be possible and this will enable the management of the error in many ways, highlighting it, zooming on it, indicating it as a rule exception

and allowing the mistake adjustment with the selection of a new route across an area with low archaeological sensibilities. With respect to this, it is important to underline, the difficulties in finding reference standards for respect areas in case of archaeological evidence. The study of case histories about archaeological findings during the last ten years has driven us to the elaboration of a referring scheme, pertinent to the location of respect areas, based on the archaeological class and its extension. This study, according to us, stresses the importance of providing modern cities with Information Systems and rules for the expansion of complex urban contexts.

7. Customized Tools

In order to reach the target we described before, we designed a set of tools tailored for the archaeological needs. We have grouped these tools in a toolbar, called “Archeo Toolbar”, that the user can load on his personal project, using ArcMap. We chose to implement our software using a COM development language; more in detail we used Visual Basic language and we created executable code saved as a Windows dll library. Deploying our software stored in a dll library is very simple: users can register the dll on their system using ArcMap customize functionality and then, from that moment on, Archeo toolbar will be available directly from ArcMap GUI. Archeo toolbar contains tools developed using VB and ArcObjects COM library. ArcObjects library is the COM Library distributed by ESRI Inc, useful to customize ArcGIS. We created a customized editing tool useful in managing the editing phase. We designed our data model introducing a great number of relationships in order to better represent some aspects of archaeological reality. Every relationship is based on the use of keys field, included in classes involved in the relationship.

A geodatabase relationship can be exploited directly in ArcMap without writing customized code. When you select a feature involved in a relationship ArcMap directly shows related objects, making the analysis more efficient. In order to exploit this functionality we must correctly populate the feature inserted in the geodatabase, populating the key fields; in a simple relationship we have to insert the Origin-PrimaryKey for the Origin Class and the OriginForeignKey for the Destination class. In this way the logical relationship has been physically implemented.

Our editing tool automatically writes a correct unique value in the attribute representing a Primary Key. When a user inserts a new object in the geodatabase the customized software opens a form showing all possible origin objects. In this form the user can click a single object making it blink on the ArcMap display. If the blinking object is correct, the user can confirm and the editing tool writes the correct foreign key in the editing object. In this way the relationship has been physically implemented.

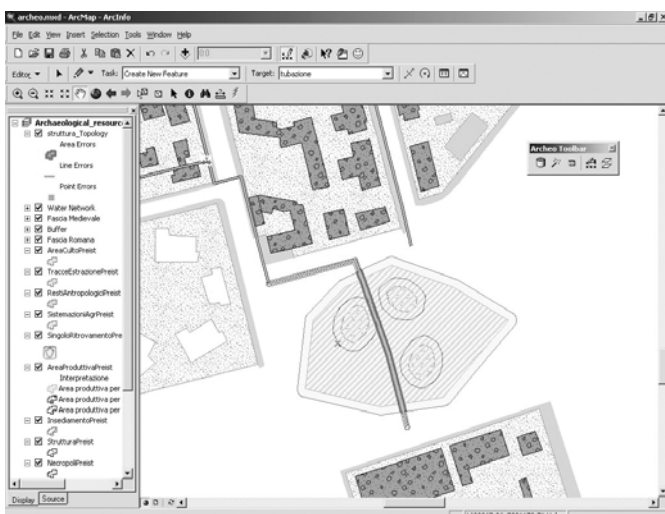


Fig. 2. ArcMap. Topological mistakes and Error Inspector tool set.

8. Buffer Wizard

The user can open Buffer Wizard pressing a button in the Archeo Toolbar. This wizard lets the user create buffer features for every archaeological object stored in the geodatabase. He can choose to create fixed value buffer polygons or customized buffered polygons using buffer distances stored into an attribute of the object. Every buffer polygon has an attribute describing the type of the object; this is useful in order to create a different symbology for every feature. The process of creating and managing buffer polygons for archaeological features can be iterative so it is also possible to delete every buffer polygon using a functionality in the buffer wizard; the user can so populate buffer feature class again developing his analysis.

9. Topology and the Topology-editing Tool

As described before, one of the main purposes of our application is to aid Utility Companies to design networks in an ideal city. Archaeological geodatabase contains a topology class. Topology allows the user to create topology rules that are helpful during the editing. More in detail, main rules avoid that network edges can overlap archaeological objects and their buffer polygons.

The topology-editing tool is well integrated in the standard ArcMap editing tool. When designer finishes his network object sketch on the map, topology tool validates the geometry of the new edge against topological rules. Topology errors are shown on the map. The designer can see the errors at once and correct them, trying to design a new route for his edge.

10. Conclusions

Our aim in elaborating this work, considering the specific characteristics of the data model, has been the realization of GIS functions based on the use of tools based on data model planning phases. To create the model we have adopted object-oriented technology. The CASE tools, have represented, during the planning phase of our Geodatabase, a moment that cannot be disregarded from the operative steps that constituted the building process of the information system.

One of the reasons that makes planning a fixed course in information systems projecting is the high sharing possibility of the elaborate product: it is usable in different working environments and in different research contexts.

We have realized that time upgrading in structuring databases is not a secondary moment whether on an informative level (horizontal) regarding the organization of tables and relations, or concerning the management (vertical) of generalizations about properties and methods among geometric-spatial feature classes, that are visualizable on a digital cartography. Our model is extremely flexible and it may be used for the ongoing maintenance of the geodatabase scheme. If a change is needed, like adding a feature class or adding attribute fields to existing feature classes, it is possible make the appropriate

changes to the UML diagram and reapply the model to update the geodatabase schema. According to this view the result of this work could be defined an “open model”, a template composed of standard macro-classes usable in different projecting contexts; these are opened and updatable.

The geodatabase resulting from this model is a flexible tool, easy to update and very simple to populate if a data model has been structured before, with all the informations about relationships, attribute domains and fields.

On the other hand it is possible that the risk on defining these tools is a rigid standardization of data during the conceptual elaboration of the model, a way for the ‘hyper codification’ of human behavioral variables. This problem has been overcome with the creation of macro-classes, in which the interpretative level is given by their interaction inside their cultural-historical contexts.

11. Future Developments

Our work is still at a developing phase, but the intent is to implement the model and its functions. Future developments regard predictive analysis for alternative network routes during utilities planning phases, when these interact with the respect areas of archaeological finds and the investigation of the role of the third geographical coordinate, the z value.

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