Topological Data Model for Interactive 3D-GIS Systems. The Particular Case of the Underground Sewerage System

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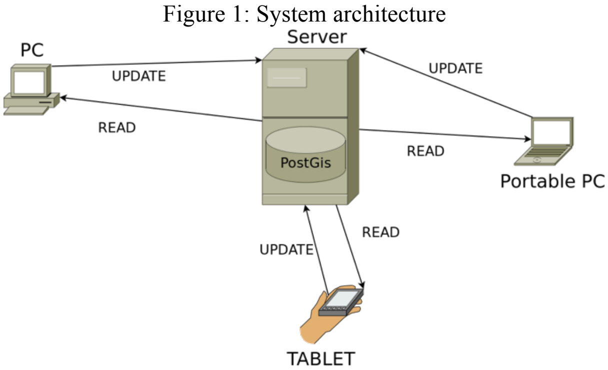
Abstract

3D-GIS are sophisticated tools for visualizing, managing and analysing data of spatial nature in 3D. Current GIS with 3D capabilities are still far from being appropriate to be used in all phases of the urban infrastructure administration. In this paper, we present the topological data model defined for most of the infrastructures in the subsoil. 3D coordinates allow to solve one of the most important handicap: the direct visualization is not possible. We focus in the particular case of the sewerage system using real and current data. Some of the most important analysis operations are performed by means of the graphical interface with 3Dcapabilities.

1 Introduction

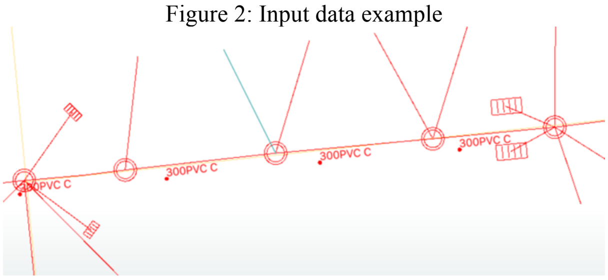
Underground infrastructures have particular features that make difficult their management: different facilities of very diverse nature may coexist in the same place, but with the peculiarity that they are not visible to the naked eye [8]. As a general rule, there are not standardized tools for managing their information [10]. Sometimes they take advantage of the spatial character of GIS, but with two-dimensional representation. The main problems underlying their management are: lack of information of old infrastructure, obsolete data in the database because of the lack of updating on the maintenance process, as well as lack of accuracy in positioning when digging the ground [5]. The main challenge nowadays is the integration of 3D-GIS is in the entire life cycle of the dataset representing such infrastructure: design, creation, manipulation, visualization and analysis. 3D systems should not be only useful for visualization, but also for analysis and data update in situ, that is, by means of devices working ubiquitously.

Figure 1: System architecture



In this paper, we describe the data model for a system with 3D-GIS capabilities for efficient management of underground facilities, using the client-server architecture depicted in Figure 1. The server maintains a spatial database in PostGIS. The client side visualizes, interacts and also modifies the information if necessary. The advantages of this scheme are mainly two: the client may be any device with certain graphics capabilities and can be placed in any site with an Internet connection.

Figure 2: Input data example



2 Data model

The input information about sewage management and water supply was given by the municipal company by a single DWG (see Figure 2). In general terms, X and Y coordinates are consistent when displaying this information, but the third dimension is not available.

Firstly, the input data file is extracted into tables with attributes. The second phase is to construct the topological relationships by means of computational geometry algorithms. The main objective is finding the undefined connections between linked elements of the same or different layers. This representation scheme separates the geometric and thematic aspects of the subsurface entities in both, database and memory designs. The geometric entities are considered as the data core, and they represent the position of any entity in the space. Basically, there are two types of geometric entities: those located in one specific point in the space (VertexObject), and those needing two points or a line to be defined geometrically (PolylineObject). The first case are drainage wells and box or inspection chambers. Line entities are pipes, whose geometric representation is given by a single line-segment or a poly-line. Additional tables provide the rest of thematic information.

connected by means of a LinkObject. Summarizing, this design allows mainly two objectives:

- Add topology to the completely disconnected input data like a graph. This makes possible an efficient data analysis.
- A pair of tables maintain the geometric entities from all layers of the input data, but distinguishing each of them when necessary. This makes more efficient the spatial operations in the database.

Figure 3: Line segment objects definition in the database

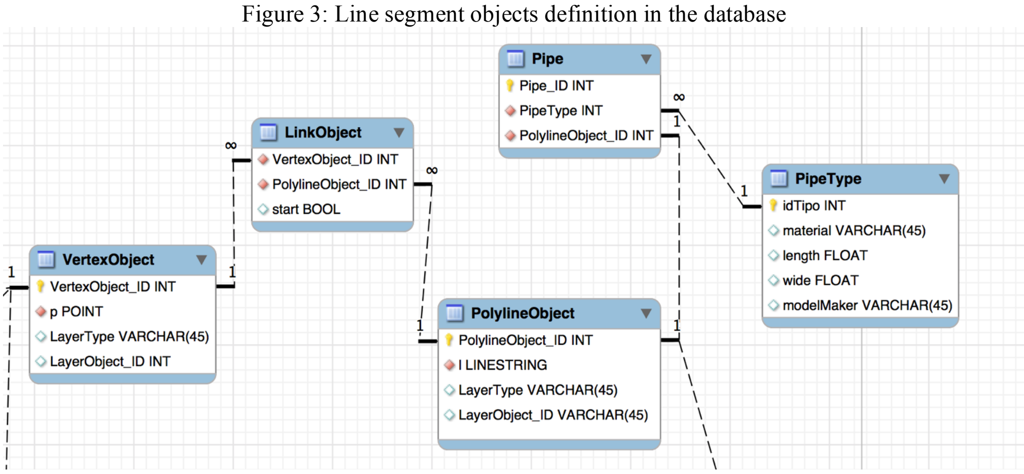
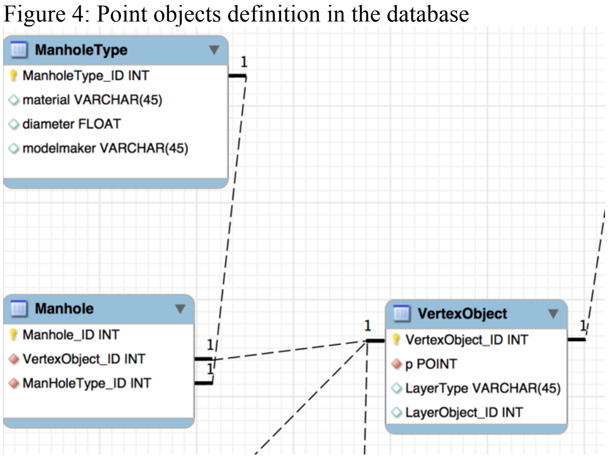


Figure 4: Point objects definition in the database



2.1 Database

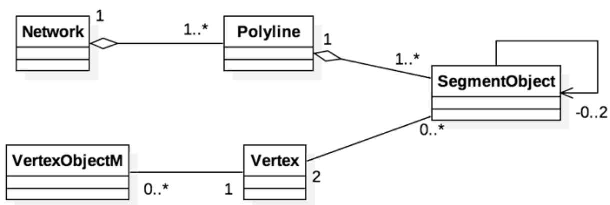
The database model is depicted in Figures 3 and 4. The first shows the relationship between Pipes, the sewerage entity, and the rest of geometric elements in the database. A Pipe is the thematic entity defined separately from its geometric representation, the PolylineObject. The second one shows the relationship of point-based sewerage entities (drainage wells or boxes), with its geometric entity.

The relationship between a PolylineObject and a VertexObject is ”many to many”. Hence, both entities are

2.2 Memory data model

Maintaining a different data model in memory allows all these geometric entities to be interacted and edited using the application interface while visualizing and navigating with the scene. The database is then updated. These operations can affect any vertex in the scene, even those forming a poly-line. The UML class diagram is defined in Figure 5.

Figure 5: Geometric classes in memory



3 System operations

In our system, the available operations are the following:

- **Selection** is one of the most powerful tools for geometry management, and the first step to interact with the scene by clicking on the geometry. Depending on the key pressed, the picking may provide different functions. Selection can be associated to vertex or segment objects stored in memory.

- **Geometry editing** can be performed in situ in order to solve errors in the input data or design new infrastructures, for instance. In this approach, this process is always performed in the vertices, but it can be affect to only one (Figure 6) or the whole polyline.

Figure 6: Geometry editing

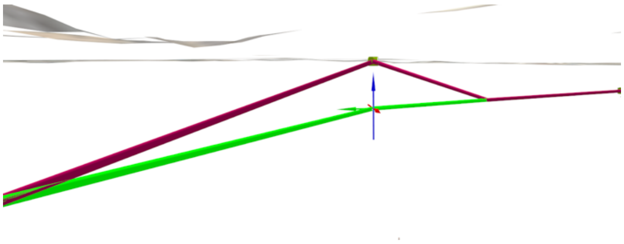
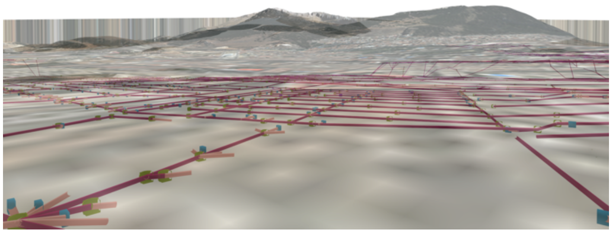


Figure 7: Sewage visualization including terrain features



4 Conclusions and Future Work

In this paper, we summarize the process of transformation of 2D non-topological layers into a complete and topological data model for 3D-GIS systems (see Figure 7). We have defined two different but related data models for the spatial database and memory.
As future work, we consider the definition of an CityGML Application Domain Extension (ADE).

References

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