



3D GIS TOOLS FOR SUBSOIL MANAGEMENT

HERRAMIENTAS SIG 3D PARA MANEJO DEL SUBSUELO

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Abstract:

Applications of Geographical Information Systems (GIS) on several archaeology fields have been increasing during the last years. Recent approaches in these technologies make possible to work with even more realistic 3D models with the so-called GIS 3D. However, these systems are currently far from being the perfect tool to integrate the subsoil management in Archaeology. In this paper we focus on the state of the art in 3D GIS for subsoil management as well as the hybrid subsoil model for 3D data management.

Key words: virtual archaeology, 3D GIS tools, 3D subsoil management

Resumen:

Las aplicaciones de los Sistemas de Información Geográficos (SIG) en muchos campos de la Arqueología se han ido incrementando en los últimos años. Las nuevas propuestas en estos sistemas permiten trabajar con modelos cada vez más parecidos a la realidad con los denominados SIG 3D. Sin embargo, estos sistemas actualmente distan de ser la herramienta ideal para el manejo del subsuelo en Arqueología. En este artículo nos centramos en el estado del arte en los SIG 3D para manejo del subsuelo y también en un nuevo modelo de datos en 3D, el modelo híbrido de integración de información espacial.

Palabras clave: arqueología virtual, herramientas SIG 3D, manejo de modelos 3D del subsuelo

1. Introduction

The three-dimensional modeling of archaeological environments is one of the pillars of the virtual archaeology, because it allows to display an environment that no longer exists based on the remains found. The 3D recreation using consolidated techniques of computer graphics are focused on various elements, such as the objects extracted from the excavations on the ground and also the architecture and landscape that locate these vestiges to recreate them as they were in ancient times (Feito *et al.* 2010).

Emerging technologies applied to archaeological heritage have led to the resulting digital or virtual archaeology, basically aims at research, documentation, preservation and dissemination of the sets of asset value, scientific, educational and outreach purposes. One of the biggest challenges facing professionals who are dedicated to the study of assets is to explain - to the general public or the rest of the scientific community - items from the archaeological settlement with which you are working. This is sometimes difficult even for a specialist, if we consider a complex set of walls, holes, decorations and furniture. Therefore, generating three-

dimensional computer aided models are valuable tools aimed primarily at professionals working in the field of cultural heritage and secondly, for the general public, the scientific community and for teaching.

However, the strong spatial character of the vestiges makes some scientist raise to work with Geographic Information Systems (GIS). Nowadays, GIS are under development (Robles *et al.* 2015) and evolving in order to increase their features and possibilities. Three-dimensional visualization is one of the most notable improvements being included in many GIS, both commercial and Open Source. In geometric terms, existing methods for modeling these systems can be classified into three categories: vector, volumetric or hybrid (Shen *et al.* 2006). In overall, most often 3D GIS focus exclusively on the vector model (Whang 2006). However, for many applications it is also needed to handle those models obtained directly from the data source in order to represent volumetric models more efficiently (Fisher-Gewirtzman *et al.* 2013), such as layers of an archaeological excavation. Therefore, at present some authors are beginning to consider the concept of hybrid integration models for the joint management of the raster information vector (Becker *et*

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al. 2012). In (López-Fraile *et al.* 2014), it is described the use of GIS in studies for micro-spatial in Paleolithic settlements, obtaining a topographical database associated with archaeological one.

Since our environment is 3D, the obtained geo-knowledge must be in 3D. This involves a set of challenges which are still pending to be even properly defined. The integration of Computer Graphics and GIS which will allow us a better approach for true 3D GIS. The application fields are relevant in Archeology where the study of subsoil is essential.

2. Overview of the existing 3D GIS for subsoil management

In this section we describe several features of 3D GIS software products for managing subsoil solutions. These have been chosen to have a particular aspect which make it special in the context 3D GIS. However, the expansion of GIS in specific 3D environments is not quite complete. Usually real 3D representation is not obtained but rather 2.5D models. They are those extruded from 2D information, for instance prismatic buildings obtained from their footprints.

We now go over current GIS tools with 3D capabilities and discuss their potential for being used in 3D subsoil management.

ArGis: It highlights 3D Analyst performed by means of two extensions and two specific modules that are supported by a set of tools (3D Analyst Tool). The latter facilitates working with various 3D vectors, raster and TIN elements.

ArcMap is the basic module of Arcgis. It provides the following features: methods of analysis and creation of 3D surfaces, visualization of surfaces, scanning and incorporation of 3D symbols. ArcCatalog is the main module for data management. The key functionality previews 3D data and also generates new layers and properties for 3D visualization.

Together with the two previous extensions, 3D Analyst incorporates two specific modules. ArcScene with which enables the visualization of multilayer 3D data, the creation of surfaces (TIN or raster), and surface analysis. Also, it allows comprehensive geo-processing of digital terrain models, including those from LIDAR data. It is also possible to change views and combine different sources of information and as well as modify them.

However, ArcGIS does not support volumetric data (Raster 3D), the developer community is the final responsible for creating additional modules for specific scenarios such as Geology. Further, all representation is based on 2.5D, therefore there are not real 3D integrated models.

Grass: Their use has been done in various projects in Archeology (for example Bezzi *et al.* 2006).

Grass is able to perform various processes on models for digital terrain surfaces which are always considered 2,5D. The model can be obtained from importing formats such as DEM or TIN. Models can be generated using digital interpolation from contour or from a set of given points. It is also possible to work with data from laser

sensors. 3D modeling in Grass covers both 3D vector elements and 3D raster elements (volumes).

It is possible to import from files of points (x, y, z) or from a set of specific ones. It is also possible to obtain volumetric models by joining 2D raster layers. Grass offers total extension to 3D from classical algebra of raster maps. It is also possible to get 2D sections, calculate statistics and export data to ASCII or VTK formats.

In general terms, Grass is a very versatile and free distribution tool that can be used joined to many different independent modules and spatial data bases, such as PostGis or Oracle Spatial. The major drawback is 3D visualization. In many cases the results are better displayed using different tools.

Engage 3D: This is the 3D tool of MapInfo whose accuracy in 3D data visualization has been proved with both raster and vectorial data. Voxel visualization is a desired feature for Archeology since objects and terrain layer disposition have volumetric nature.

The software allows different format conversion but the analysis functionality is very limited for this type of data in 3D. Figure 1 shows the resulting model after integrating DEM information, and layers of buildings and underground infrastructures.

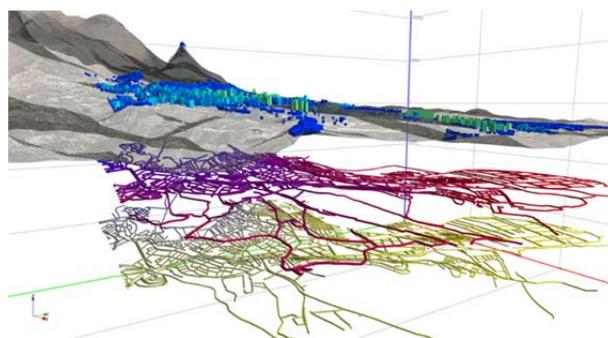


Figure 1: Engage 3D for underground infrastructure.

3. The Subsoil Management Use Case

This section details a possible application for the field of Archaeology. In 2015, the GGGJ group obtained National funding with the Call: Proyectos de I+D “EXCELENCIA” and Proyectos de I+D+I “RETOS INVESTIGACIÓN”, for developing a R&D project titled “Contributions to Smart Cities. Towards a subsurface 3D GIS” with code: TIN2014-58218-R. This project will help as brief example in order to better understanding and interconnect the applications of 3D GIS solutions to the subsoil management and the virtual architecture of cultural heritage.

Numerous services that make a city to work properly are in the underground. Along the history, humans have used the subsurface as a form of shelter or a place from where to obtain resources. At present, much of the infrastructure relating to urban development are under the surface to preserve the space available on the cities, reduce the flow of traffic, provide security and isolation facilities (Herrador *et al.* 2016) this technology can be also applied to Archeology. Many archeological remains are or have been underground and their spatial arrangement is under study.

Underground infrastructures also require this functionality for an efficient management but the third dimension is normally provided with a high level of abstraction. The inclusion of 3D models of various layers of soil and infrastructure elements - such as tunnels - is the next step to achieve substantial progress in the suburban area of management (Fig. 2).

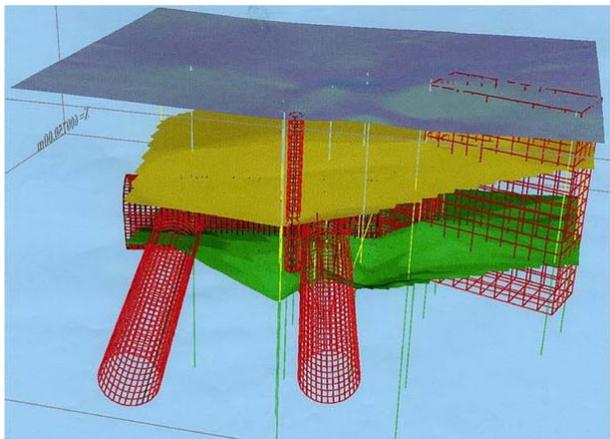


Figure 2: Subsoil representation with tunnels.

Obviously, 3D models allow direct display of objects within the soil layers as well as the spatial interaction or relationship between them. The model may reflect this disposition even after being excavated. The camera or virtual observer can navigate through the entire model and it also could be connected with spatial data bases by means of a simple picking operation. Figure 3 shows an example of underground pipeline infrastructure supporting all these desired features.

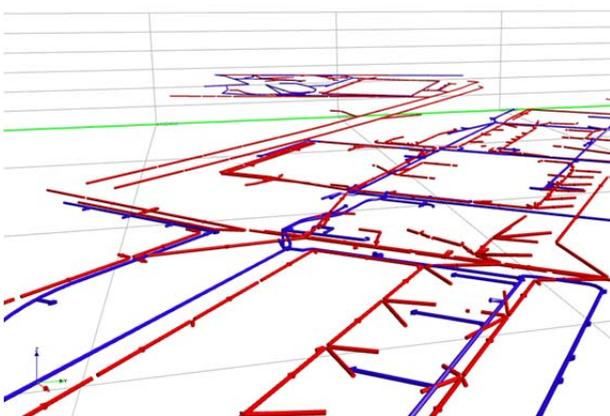


Figure 3: 3D layer disposition.

Recently, some authors are beginning to consider the concept of hybrid models of integration for the joint management of volumetric and geometric information (Becker *et al.* 2012). A hybrid system should not modify or change the nature of the data, but rather should integrate both representations under a model capable of managing both at the same time, and providing results regardless of their nature. This kind of models have not been worked generically, but focus exclusively on very specific types of scenarios (Lee *et al.* 2008).

In subsurface analysis by integration of different data sources and formats, the work of (Lei X. *et al.* 2015) focused exclusively on integration of different types of

input data for analysis of the soil layers without direct expansion for general use (Fig. 4). CAD/CAM has hybrid models for the management of regular geometric objects, but they are non-existent for the representation of information with irregular nature.

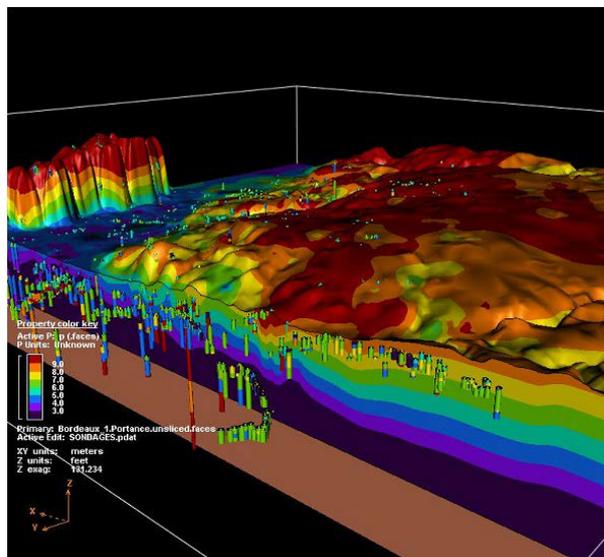


Figure 4: 3D rendering of exploration on the ground in layers.

The vector representation would focus more on visualization and analysis of the surface of objects, or in our particular case, the analysis of the length of pipelines, connectivity, slopes, etc. On the other hand, the volumetric representation or voxelized would be responsible for the global representation model of the interaction of the different soil layers with vector data. Advances in this field have been insufficient in last years.

Our research group has begun working with volumetric libraries, specifically OpenVDB software. This library enables you to store large volumes of spatial information using efficient mechanisms for handling and storage. The possibility of using the tree structure of this library to link to other vector data structures representing geometric information, is a starting point to address the problem of integrating posed models.

Similarly, another objective would be to cover the inclusion of the temporary variable in the system, which allows reliably reflect the changes undertaken over time. Driving time trends in such systems would help to change work environments to allow the location of obsolete nature infrastructure, analyzing the possible expansion of the design of future facilities, etc. The process that efficiently manages temporary variables is more complicated than simply adding a date data type to manage the systems (Eshel 2011).

4. Conclusions

In the coming years it is expected true 3D utilities integrated in GIS in order to transcend the simple use as 3D viewers, allowing better modeling of reality. At the same time, their use shall be provided in a greater number of devices, especially mobile, which will open new applications for distributing archaeological elements. This will provide a future approach for viewing and interacting with information, allowing us to achieve

new graphics capabilities for the development of new languages for 3D visualization using web applications (Held *et al.* 2004).

In general, there are few research groups consolidated in the urban 3D GIS work, although this trend is modified in recent years to Smart Cities considered as an objective of Horizon 2020. In Europe stands out by Dr. Sisi Zlatanova, Technological University of Delft (Netherlands), with long experience in this subject and with some members of the applicant research group have recently worked, and whose contribution will also be of special interest in this project. Another research group with experience in GIS and urban modeling is the Dr. António Augusto de Sousa, Faculty of Engineering,

University of Porto (FEUP), who have collaborated (Robles *et al.* 2013) as a possible planned joint work. Contributions of the Graphics Group at the University of Jaén are also recent regarding urban 3D GIS (Robles *et al.* 2012).

Arqueology may be benefited with all these achievements regarding 3D GIS and hybrid data models.

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