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Short and Project Papers

Architectural 3D Modeling for a 3D GIS Web-Based System

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Abstract
We describes a 3D GIS system entirely founded on Google Earth (GE), designed to make available on this platform high-quality 3D models of one of the architect Andrea Palladio, conceived as a metaphor for navigating through the data and developed as a scalable applications able to allow the use of the same database for different user simply filtering the data according to the specific requirements.

Categories and Subject Descriptors (according to ACM CCS): I.3.5 Physically based modeling; I.3.7 Virtual reality; I.3.7 Color, shading, shadowing, and texture

1. Introduction

The introduction of the third dimension aimed at storing and managing documentation about 3D objects, offers a more intuitive way to access and manage different kinds of information. The availability of digital 3D rendered models exceeds, in fact, the simple possibility of developing photorealistic reproduction of the 3D real object, and it makes available all information in a visual and integrated way limiting errors due to granularity.

The "*Palladio 3D Geodatabase*", developed with the Centro Internazionale di Studi di Architettura Andrea Palladio (CISAAP), is a complete 3D Web geo-database in which 3D models integrate a comprehensive Palladian information system, in order to become the preferred interface for accessing this database and giving access to the data relating to individual buildings by Palladio. This application allows a complete representation of architecture whose complexity can hardly be approached and understood through textual or iconographic documents. The added value of "*Palladio 3D Geodatabase*" - thanks to the visualization in real-time at high-quality rendering inside the geo-visualization system of GoogleEarth - is given by the inclusion of the buildings in the territory. It allows to discover unknown relationships between the villas and the environment, to evaluate their architectural occupancy and to quickly access a complex system of information collected by several extensive researches developed by the CISAAP along the years.

This 3D digital archive represents a complex cognitive system for Palladio's opera finalized through:

- 3D digital models representing the reality and, as metaphor of the observed objects, allowing a direct and semantic knowledge of the data;
- 2D textual and iconographic materials approved and critically analyzed by the CISAAP International Scientific Committee, composed of the most qualified researchers of Palladio's opera;
- Development of a new web-based architecture allowing a multi-user access from different platforms, using defined standards.

Figure 1: *"Palladio 3D Geodatabase", Villa Badoer, Fratta Polesine: main browser interface*

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The framework, carried out using different technologies and tools, widespread multi-platforms and standards, has been developed with the aim to solve three main challenges typical of 3D models for GIS construction in the field of historic building:

- How to build 3D models from real-world;
- How to structure a 3D database able to drive the display of the documentary materials (documents, photos, drawings) through an informative system;
- How to move from single experience to a system in which all the operators work in the same way and using similar technologies.

The paper illustrates in section 2 the related works; section 3 describes methods and workflows applied to build multi-resolution and semantic structured 3D models; section 4 illustrates the techniques and procedures applied for the visualization in real-time rendering; section 5 reports the description of 3D Web-based knowledge system; concluding remarks are reported in section 6.

2. Related works

Realizing 3D Web GIS present a series of difficulties that can be summarized in the following points [RP08]: (a) conceptual model, (b) data collection, (c) visualization, navigation and user interface development, (d) Internet access, (e) spatial analysis. The availability of 3D semantic models organized as cognitive systems allows to have geo-object items in a 3D GIS and an improved topological control that allows a semantic approach to the classical problem of modeling through different levels of detail. 3D modeling pipeline must be based on the accepted and general convention of architectural analysis whereby structures are described as a series of structured objects using a specific architectural lexicon. The component parts can be reassembled using a 'put-together' method as previously reported by Stiny and Mitchell [SM78]. A lot of experiences have presented a methodological approach to the semantic description of architectural elements [DFV07], defined a method able to describe the shape of 3D objects [USF08] or showed how attribute grammar formalism can be used as a 3D modeling language [SDP09]. Semantic classification has also been recently used for procedural modeling of architectures [MWH06] and city modeling applications [EZ08]. Based on a web server infrastructure, this Information System allows intuitive and easy accessibility for all users and the independence from proprietary software. De Luca et al. [DFV07] have developed an application that allows comparative studies starting from heterogeneous data and models using a simple and intuitive web-based interface. The multiple representations of architecture buildings and their associated information have been organized around semantic models.

3. Multi-resolution 3D modeling

Our aim is to obtain 3D models allowing a semantic reading of the reality and the design intents throughout the interpretation of the shapes described by the model itself. Therefore our model construction pipeline consists of six different steps (figure 2):

1. acquisition of metric and formal data of the buildings
2. 3D modeling based on a semantic structure
3. model editing
4. ambient occlusion mapping
5. KMZ file construction
6. 3D model positioning in GE.

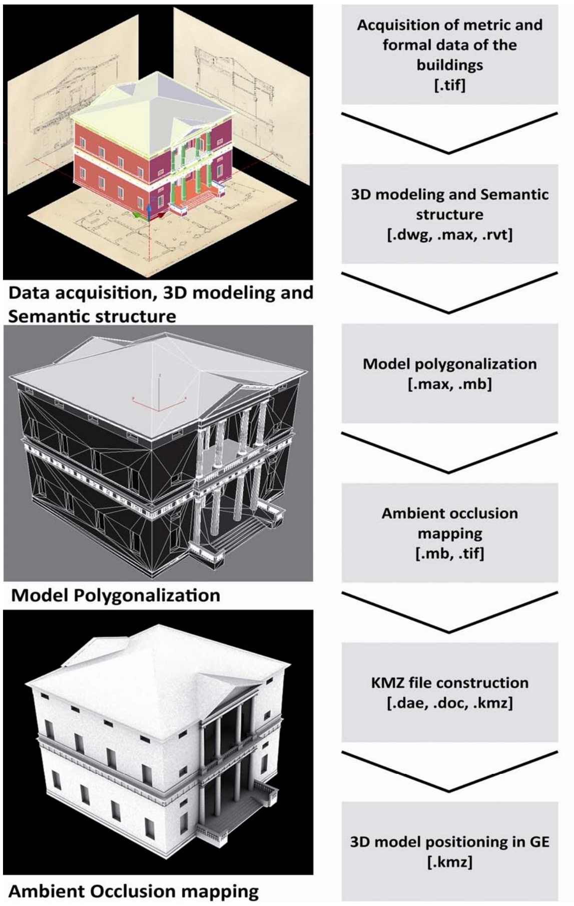

Figure 2: *3D Model Construction Pipeline*

Our 3D modelling system allows to obtain semantic models ready-to-use as a knowledge system (figure 3). This type of numerical organization allows to manage the 3D models as multi-resolution models and to subdivide them in consistent and hierarchical subset of a defined number of polygons to be included and visualized in GE.

The pipeline starts from digital scans of the handmade survey of the "*Corpus dei rilievi delle fabbriche palladiane*" performed with the support of the Italian National Research Council from the CISAAP. Drawings consist of a set of tables at different scales depending on the type of representation and detail, with an approximation of 1.75 ÷ 3.5 cm depending on the original scale and digital reproductions and scans.

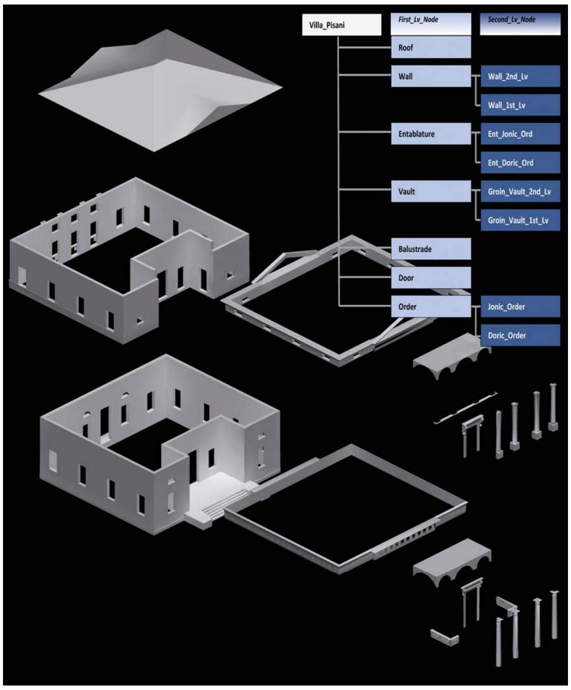

Figure 3: *Villa Pisani, Montagnana: 3D Model Semantic Structure*

The pipeline provides to use different commercial software with the only condition that: (a) the geometries used will be B-rep or NURBS; (b) using FBX or OBJ export file in order to ensure geometric interoperability between different pipeline steps; (c) three different levels of detail; high, medium, low. Autodesk Maya, indeed, has been choose for realizing some pipeline key steps: model editing (segmentation, polygonalization, optimizing mesh); AO mapping; export in DAE format, in order to generate the components of the final KMZ file. It consists of a single root KML document (notionally "doc.kml") and a series of referenced files (DAE, TIF or PNG) in the sub-directory “models”: DAE files describe geometry; TIF or PNG files include mapping information of the corresponding DAE files.

4. Model visualization: Real-Time Rendering and Ambient Occlusion texture mapping

The typical way of drawings by Palladio is a flat representation characterized by no depth, as can be seen in “*I Quattro Libri dell’Architettura*”: a collection of two-dimensional drawings of plan and elevation representing the relationship between them. Therefore we looked for a form of representation that could bring-out volumes from Palladio’s flat drawings and resolving the typical problem of displaying 3D models in GE: the use of a simple Gouraud shading.

In order to show the true Palladian schemes in 3D, we applied a render-to-texture AO techniques for shading. The process requires a pre-process of the model to export the textured wire-frame correctly in Google Earth. The base shader library from Mental Images provides a set of utility shader helpful to gather and control occlusion information. Our implementation follows Occlusion tutorial with Mental Ray [Ber05] and is accomplished at the shading level through the *mib amb occlusion shader*. Problems in this pipeline are typical visual artefacts caused by:

1. 3D Model Tessellation: the 3Dmodeling software inverted surface normal randomly, and generated a poorly formed mesh;
2. Lightmap Texture Mapping: lightmaps are essentially a rectangular grid of polygons overlaid onto whatever surface texture is already present on a polygon. Because of this, extra thought is required to devise a means to reduce aliasing errors;
3. Sampling Error: samples may be obscured or ‘contained’ inside the ‘solid’ of the geometry. If any part of the rectangle represented by the ‘inside’ sample lies ‘outside’ of the geometry, it will be visible and most likely will have an incorrect intensity. This results in lighting that ‘creeps’ underneath walls and corners;
4. Sampling Rate: Mental Ray uses the same resolution for every lightmap, and assigns a unique lightmap to every polygon. Instead of increasing the resolution of the lightmap for larger polygons, it scales the lightmap to fit the dimensions of the polygon.

The segmentation process adopted gives an excellent solutions to the problems of point 2 and 4 just using a single atlas texture map for each group of semantically similar elements and using the appropriate dimensions for each group from 512x512 to 4096x4096. Point 1 requires only the control of the normal direction and point 3 the control to avoid intersection or overlapping of surfaces or solids, but this is a hypothesis of our modelling pipeline.

5. The 3D models in the GIS system

The framework allows to display 3D digital models in real-time with high-quality rendering in GE platform, providing a useful interaction between the 3D content of the territory, the models and the documentary archive. The use of GE has inverted the roles of web browser as application and map as content, resulting in an experience where the planet itself is the browser. GE allows to create and share all sorts of dynamically-updating data over the internet. KML file allows to overlay many basic data types, useful for weather data, such as images, point data, lines, and polygons. The KML/GE combination provides the ‘glue’ to integrate data sources and facilitate interaction, and the basis for geo-location of Palladian buildins and the rendering engine of 3D models thanks to the GE plug-in.

The 3D models semantic structure allows to organize each single sub-element as a node, linked to a file that can be stored separately from the other ones belonging to the same artefact. All geometry-parts are associated with a semantic meaning, and each semantic item is further described with specific attributes. Each part is then connected to series of information created to facilitate the retrieval process in a semantics-based context. Furthermore a semantics driven visualization enhances usability of the model. Semantic structure is then exploited to obtain multi-resolution representations. The link between 3D models and 2D documentation is bi-directional, so that it is possible to access data from models and vice-versa, using the same web based interface, and the system can be easily linked with any kind of database available on web.

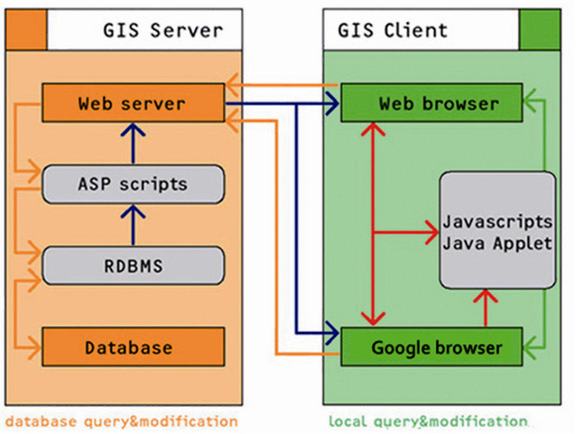

Figure 4: *"Palladio 3D Geodatabase", key components*

The "*Palladio - 3D Geodatabase*" has been designed and developed for a multi-purposes use: cataloguing, documentation, preservation, management of archaeological heritage, tourism and for external communication through the web portal. The application is organized as a Rich Internet Application (RIA), based on 4 key components (figure 4):

- open relational database management system (RDBMS);
- web server;
- web browser and virtual reality browser;
- web server language side-oriented together with a software for dynamically recalling the contents.

The user interface is a key point of the project since it is completely different from the usual mode of information visualization on a web browser. Our Graphics User Interface (GUI) - a combination of HTML forms and KML/KMZ models - allows the user to control the different operative modes, to select specific inputs, to check the current state and to surf inside the applications, through four modules (the menu and the working area at the top of the screen; the complete view of the urban system or/and the site where the building is located; the browser; the numerous windows that can be opened in GE as a virtual table) and the several queries available, in order to obtain additional information regarding the object of interest or to search artefacts that meet specific requirements.

6. Conclusions

Our work has been focused on defining a framework able to give new possibility to digital 3D web-based GIS system, putting the basis for several platforms with different purposes: tourist information, scientific researches and projects, management, conservation and maintenance activities of the Palladio's work. This system is completely geo-referenced using Google Earth and 3D model based. The framework is designed in order to be scalable in the visualization and the client PC systems, from large screen displays and high-end workstations to desktop monitor displays and low-end PC. The application could be used with a minimal customization to manage other visual database of architecture.

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